Technology Challenges for Clouds

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I/O Modeling Plan: What is the Weather
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Agenda

• Who is Instrumental
• Challenges for Cloud architectures
• Challenges for Cloud customers
• Cloud storage technology review
• Next steps
Who is Instrumental

• Founded in 1991
  – Headquarters in Bloomington, MN
  – Office in Reston, VA

• Core team of professionals
  – System Analysts and Architects
  – Broad experiences with challenging problems

• Focused on technology
  – Performance-based Professional Services
  – HPC computation, storage & networking
    • UNIX, Linux and Windows
Professional Services

• Instrumental delivers performance
  – Specializing in helping customers achieve a sustainable, competitive advantage
  – Our Mission - “To deliver excellence and innovation in advanced computing environments”

• With proven capabilities
  – Computation, storage, networking and usability
  – Architecture, design and integration services
    • Performance management
    • System analysis and optimization
    • Modeling and simulation
Instrumental Expertise

• Complex Challenges
  – Exploding costs & tighter budgets
  – Liability and reputation issues

• Rigid Requirements
  – Not always performance based
    • Control and usability

• Scalable Solutions
  – CPUs, memory, I/O and networking
    • 10,000s of processors
    • 100s of TB/sec for the file system
    • 10s of Petabytes in the file system and HSM
Vendor Neutral

- We do not resell anything
  - Hardware or Software
- Nor are we compensated for recommendations
  - No finder’s fees
  - No commissions
- Direct support of many agencies
  - Trusted partner
    - Vendors respect us and sometimes fear us 😊
- Support for Prime contractors
  - Sometimes we are asked to be the integrators for complex architectures
Challenges for Cloud architectures

Things often not considered
Obvious Issues

• Security
  – This is considered the biggest challenge
  – This is at best a very difficult problem to solve given current state of security stack
  – Desire of hostiles to gain access

• QoS
  – No end-to-end way to provide consistent services
  – No planned changes in POSIX to allow this
Non-Obvious Issues: Cost

- Network bandwidth costs
  - OC-192 is equal to about a single 10 GbE
  - Cost is well over $100K for the line without hardware
  - A server 2 port 10 GbE NIC is $350
  - 10 GbE switch ports are far less than OC-192 network gear

- Fast network bandwidth is needed for many access and replication tasks
Non-Obvious Issues: Latency

- Famous quote from John Mashey
  - Money can buy you bandwidth but latency is forever
- Protocols for file systems do not address the latency problem
- Applications need to be written to address this
- Estimate latency from NY to CA is about 35 milliseconds
  - This is ~7x fastest spinning disk’s latency
  - Latency will have an impact on:
    - Small files and small I/O requests
    - File and directory lookups
Challenges for Cloud Customers

Technology Challenges
Some of the challenges

• Streaming performance impact
  – Local disks and networks vs. remote disks and networks

• Latency impact
  – Likely 10x different given switching and protocols

• Protocols for multi-user access to same file
  – POSIX locks file to prevent out of order writes
    some remote protocols bypass POSIX
    • NFSv3 for example
Cloud storage technology review

Replication for large storage systems will be costly
Impact of Disk Technology on Clouds

- Next few slides step through industry published data on disk technology and the impact on cloud architectures
- First some definitions
  - Bit Error Rate (BER)
    - In telecommunication transmission, the bit error rate (BER) is the percentage of bits that have errors relative to the total number of bits received in a transmission, usually expressed as ten to a negative power. For example, a transmission might have a BER of 10 to the minus 6, meaning that, out of 1,000,000 bits transmitted, one bit was in error. The BER is an indication of how often a packet or other data unit has to be retransmitted because of an error.
More Definitions

– Hard Error

• An unrecoverable error occurs when, for example, a disk encounters an area of the media that is damaged and is no longer readable. Several retries are typically performed by the read logic until a soft error threshold is exceeded. Disk drives specify this in terms of bits read per sector that cannot be read.
Hard Error Rate for Disks

<table>
<thead>
<tr>
<th>Drive Type</th>
<th>One sector per X bits=Hard error rate</th>
<th>Byte Equivalent</th>
<th>PByte Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer SATA</td>
<td>10E14</td>
<td>1.25E+14</td>
<td>0.11</td>
</tr>
<tr>
<td>Enterprise SATA</td>
<td>10E15</td>
<td>1.25E+15</td>
<td>1.11</td>
</tr>
<tr>
<td>Enterprise SAS</td>
<td>10E16</td>
<td>1.25E+16</td>
<td>11.10</td>
</tr>
</tbody>
</table>

- By reading ~110 TB of data on consumer drives you can expect 1 sector that cannot be read
  - Currently, for all vendors, this will cause the drive to fail
  - For disk drives hard errors are a fact of life… always have been and always will be
• This time grows with each new drive generation given increased density
  – Performance increases at most 20% while density often increases 2x
• This will become untenable with 4 TB drives taking over 10 hours to rebuild (consumer drive)
Network Bandwidth

<table>
<thead>
<tr>
<th>OC Channel Speed</th>
<th>Estimated MB/sec</th>
<th>Number of Consumer SATA Drives in bandwidth</th>
<th>Number of Enterprise SATA Drives in bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td>276</td>
<td>3.37</td>
<td>3.04</td>
</tr>
<tr>
<td>192</td>
<td>1106</td>
<td>13.49</td>
<td>12.15</td>
</tr>
<tr>
<td>384</td>
<td>4424</td>
<td>53.95</td>
<td>48.61</td>
</tr>
<tr>
<td>768</td>
<td>17695</td>
<td>215.79</td>
<td>194.45</td>
</tr>
</tbody>
</table>

- How many drives are needed to saturate a channel in terms of bandwidth which is needed for replication
  - Does not include data access
- OC-768 is the internet backbone
- OC-192 POPs are few and far between even today
**Annualized Failure Rate**

<table>
<thead>
<tr>
<th>Number of Consumer SATA Drives</th>
<th>AFR in %</th>
<th>1 PB in Drives</th>
<th>1 PB Failure Rate</th>
<th>5 PB in Drives</th>
<th>5 PB Failure Rate</th>
<th>10 PB in Drives</th>
<th>10 PB Failure Rate</th>
<th>25 PB in Drives</th>
<th>25 PB Failure Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.24%</td>
<td></td>
<td>500</td>
<td>0.02</td>
<td>2500</td>
<td>0.08</td>
<td>5000</td>
<td>0.17</td>
<td>12500</td>
<td>0.42</td>
</tr>
<tr>
<td>0.73%</td>
<td></td>
<td>500</td>
<td>0.01</td>
<td>2500</td>
<td>0.05</td>
<td>5000</td>
<td>0.10</td>
<td>12500</td>
<td>0.25</td>
</tr>
</tbody>
</table>

- Vendor published numbers on best case expected number of drives to fail per day
  - Lots of factors that make this far worse
- Google and CMU study shows far greater
  - This is best case vendor data across multiple drive vendors
### BER Failures

<table>
<thead>
<tr>
<th></th>
<th>5%</th>
<th>7.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 PB</td>
<td>5 PB</td>
</tr>
<tr>
<td>Number of Consumer SATA Drives</td>
<td>1.5</td>
<td>7.5</td>
</tr>
<tr>
<td>Number of Enterprise SATA Drives</td>
<td>0.2</td>
<td>0.9</td>
</tr>
</tbody>
</table>

- This chart shows daily failure rate using 5% of drive bandwidth and 7.5% of theoretical drive bandwidth
  - Failures because of BER depend on storage usage based on statistical analysis based on ECC failures within the drive
• This is the number of Mbyte seconds required to replicate fail drives
  – How many second per day running at 1 MB/sec
• If this value- minus the number of MB/sec of the OC channel*24*3600 is positive the time to replicate is less than channel bandwidth
Implications

At 10 PB and 5% drive utilization failure rate exceeds an OC-48 channel
  – 71.4 MB/sec more is needed

Drive failures will eventually cause the loss of data

This does not take into account two drives with same data on it failing
  – It will happen

<table>
<thead>
<tr>
<th>Drive Type and Usage</th>
<th>OC Channel Speed</th>
<th>1 PB</th>
<th>5 PB</th>
<th>10 PB</th>
<th>25 PB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer SATA 5%</td>
<td>48</td>
<td>20,882,319</td>
<td>8,860,106</td>
<td>-6,167,659</td>
<td>-51,250,956</td>
</tr>
<tr>
<td>Consumer SATA 7.5%</td>
<td>48</td>
<td>19,840,727</td>
<td>3,652,149</td>
<td>-16,583,574</td>
<td>-77,290,742</td>
</tr>
<tr>
<td>Consumer SATA 5%</td>
<td>192</td>
<td>92,545,935</td>
<td>80,523,722</td>
<td>65,495,957</td>
<td>20,412,660</td>
</tr>
<tr>
<td>Consumer SATA 7.5%</td>
<td>192</td>
<td>91,504,343</td>
<td>75,315,765</td>
<td>55,080,042</td>
<td>-5,627,126</td>
</tr>
</tbody>
</table>
Next steps

What needs to be considered
• What to do about drive rebuild times
• In some cases with large data throughput, moving to the cloud is too costly
• Data loss will increase with each new drive generation
• Storage Class Memory (SSDs) will probably not help
Thank You