Enhancing Live Migration Process for CPU and/or memory intensive VMs running Enterprise applications

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With the contribution of Aidan Shribman and Petter Svard
Agenda

• Background: Enterprise Applications and Live Migration
• Warm Up
• Delta Compression
• Page Priority
• Future Works
Background

Migrating Enterprise Class applications
Enterprise application and Live Migration Issues

• Enterprise class application:
  • Bigger than average resource requirement
  • Average SAP ERP 16GB + per VM with 32 GB of swap more than common
  • OLTP system such as ERP are very sensitive to time variation.
  • Rely heavily on precise scheduling capabilities, triggers, timers and on the ACID compliance of the underlying

• Challenge when migrating such application:
  • Disconnection of services:
    • Gigabit Ethernet timeout ≈ 5 seconds (>500 MB memory left in stop and copy phase)
    • Downtime is workload dependent
  • Disruption of services:
    • Migration progressively increasing the amount of resource dedicated to itself => gradually
degrade performance of the coexisting systems / VMs.
  • Difficulty to maintain consistency and transparency
  • Unpredictability and rigidity
Warm Up for Live Migration

Increasing the flexibility of Live Migration
Warm Up

Increasing flexibility

Extended adaptive Pre-copy phase without triggering actual migration
Increased flexibility:
• “just in time” triggering of live migration

• Reduce down time
Dynamic adaptive bandwidth allocation
• Manual and automatic
Allow “hot standby”
Facilitate WAN link transfer

Utilization

Time

Trigger Warmup

Cancel Warmup

Switch to full live migration

Classic Live Migration Threshold

New Live Migration Threshold

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Experimental Results: Warm-up Summary
SAP Sales and Distribution Benchmark

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Without Warmup

Normal Service

<table>
<thead>
<tr>
<th>Memory Transfer before stopping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived Downtime</td>
</tr>
<tr>
<td>Normal Service</td>
</tr>
</tbody>
</table>

With Warmup

Normal Service

VM size: 4GB
SMP: 2 vCPU
Users: 150
Load ~ 80%

<table>
<thead>
<tr>
<th></th>
<th>CPU</th>
<th>Avg Response Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>60%</td>
<td>2.18 sec</td>
</tr>
<tr>
<td>Warm-up</td>
<td>73%</td>
<td>2.16 sec</td>
</tr>
</tbody>
</table>

Downtime under load: <1 sec
Success ratio: ~99%

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Delta Compression of Page

Limiting the impact of resending Page
Dirty Page Delta Compression

• Cache page with highest dirtying rate during send operation
• Compression Algorithm:
  – XBRLE: XOR + binary run length encoding

Vanilla (no compr.)

Delta compression

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Evaluation
Benchmark

• Memory write benchmark (lm_bench)
  • 1 GB RAM, 1 vcpu VM
  • Near ideal case
  • Downtime reduced by a factor of 100
  • Throughput increased by 63%

• Transcoded HD Video (VLC)
  • 1 GB RAM, 1 vcpu VM
  • Real-world, non-ideal case
  • UDP downtime reduced from 8 s to 1
  • Migration is transparent using XBRLE
  • 31% faster, 51% less data sent

<table>
<thead>
<tr>
<th></th>
<th>Total migration time</th>
<th>Transferred data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vanilla</td>
<td>22.1 s</td>
<td>459 MB</td>
</tr>
<tr>
<td>PRIO</td>
<td>15.4 s</td>
<td>225 MB</td>
</tr>
</tbody>
</table>

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Evaluation- SAP ERP
Sales and Distribution benchmark, load 100%

- Non-responsive on resume with vanilla algorithm
- Survived using XBRLE
- >0.5s of downtime = risk of damaging the system
- Measured downtime was 0.2s for XBRLE and 2s for vanilla
- Live Migration CPU usage directly impact (limit) the available resource for the ERP
Page Prioritization

Dynamic page transfer reordering
Dynamic page transfer reordering
Prioritizing page sends (similar to writable working set concept in Xen)
Dynamic page transfer reordering
Prioritizing page sends

Transfer order

Vanilla
Prioritized
Evaluation

Prio vs XBRLE: reveal Cache miss and compression efficiency Issue

<table>
<thead>
<tr>
<th>Working set size (MB)</th>
<th>Transmitted data (MB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>512</td>
<td>XBRLE: 600 PRIO: 400</td>
</tr>
<tr>
<td>1024</td>
<td>XBRLE: 1200 PRIO: 1000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Working set size (MB)</th>
<th>Migration time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>512</td>
<td>XBRLE: 0.07 PRIO: 0.15</td>
</tr>
<tr>
<td>1024</td>
<td>XBRLE: 0.14 PRIO: 0.15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No of rounds</th>
<th>No of pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>500000</td>
</tr>
<tr>
<td>2</td>
<td>400000</td>
</tr>
<tr>
<td>3</td>
<td>300000</td>
</tr>
<tr>
<td>4</td>
<td>200000</td>
</tr>
<tr>
<td>5</td>
<td>100000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Working set size (MB)</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>XBRLE: 1 PRIO: 1</td>
</tr>
<tr>
<td>128</td>
<td>XBRLE: 2 PRIO: 2</td>
</tr>
<tr>
<td>256</td>
<td>XBRLE: 4 PRIO: 4</td>
</tr>
<tr>
<td>512</td>
<td>XBRLE: 8 PRIO: 8</td>
</tr>
<tr>
<td>1024</td>
<td>XBRLE: 16 PRIO: 16</td>
</tr>
</tbody>
</table>
Optimizing Compression

Making XBRL more efficient
**XBRLE**

Increase compression speed /efficiency

- Only compress unmodified data using word aligned encoding and only encodes runs of zeros
- For encoding page diffs XBRLE is:
  - Compression:
    - 20% more efficient than XBRLE
    - 20% less efficient than LZO/Snappy.
  - Speed:
    - Overall 2.5x-5x faster than XOR + LZO/Snappy
    - 11x-9x faster than the original XBRLE
- Doesn’t solve the impact of cache miss
Performance comparison
Synthetic benchmark representing enterprise workload

Higher bandwidth (1778-2286 MB/s)

Lower CPU time
Performance comparison
Live Migration Benchmark

• Compute capacity used for live migration:
  • xbzrle: 50%
  • vanilla: between 30%-60%
• Live Migration:
  • xbzrle: terminate in seconds
  • Vanilla: not able to complete in the allocated time
Future Work
Future Works

• Dynamically disable XBZRLE algorithm if the cache miss ratio is too important

• Combine Page priority algorithm and XBZRLE:
  • Cache page with highest dirtying rate
  • Eliminate unnecessary cache check
  • Eliminate page compression with low potential return
Thank You!

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Experimentations Results: S&D Benchmark with/out warm-up

Response Time (baseline) vs Response Time (warm-up)

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VM size: 4GB  
SMP: 2 vCPU  
Users: 150  

2 s response time threshold

Downtime under load: <1 sec  
Success ratio: ~99%
Phase 1: Warm-up  Duration: as long as we want

Live Migration over emulated WAN Link

Scenario 2: “Warm-up + Live Migration”

Scenario 1: “Classic Live Migration”

Phase 2: Pre-copy

Duration: ~9 min 30 sec

Not successful (human timeout) Probability of Survivability of the SAP system: ~0%

Prob <- 0

Phase 3: Frozen Transfer  Duration: ~2.16 sec

Physical Server

1 Vm: SAP ERP DB + CI

Vm Alive

ERP Alive

Emulated WAN Link:

10 Mb/s

350 ms latency

50 ms Jitter

[1%, 5%] packets drop

Shared Storage
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