CQNCR: Optimal VM Migration Planning in Cloud Data Centers

Presented By

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Joint work with Md. Faizul Bari, Mohamed Faten Zhani, Qi Zhang, and Raouf Boutaba
Outline

• Introduction
• Motivating Example
• Problem Formulation
• Proposed Heuristic
• Evaluation Results
• Conclusion & Future Work
VM Migration: Why do we need it?

• Virtualization has become a key enabling technology for cloud data centers

• Virtual Machine (VM) migration enables dynamic resource re-configuration for

  • Cost reduction
  • Maximizing utilization
  • Improving performance & reliability
Live Migration of VM

- Pre-copy live migration

- **Image-Copy Phase**: the VM image is copied from the source to the destination
- **Pre-Copy Phase**: memory pages are copied periodically
- **Stop-Copy Phase**: the VM is paused and all remaining memory pages are transferred
VM Migration Sequencing Problem

- Depending on the objective, many VM migrations can be triggered at the same time
  - Service disruption
  - High resource consumption
  - Network congestion
  - Long provisioning time

- We need to find an optimal migration sequence
  - Reduce total migration time
  - Minimize service disruption time
  - Avoid server overload
  - Reduce network congestion
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Motivating Example

Here we consider a network consisting of
- 4 servers
- 2 top-of-rack switches and
- 2 aggregate switches
Motivating Example

Example virtual networks to be deployed on the physical network
Motivating Example

Initial mapping

Final mapping
Motivating Example

Total migration time: 220 s
Average VM downtime: 4.14 s
Average VN downtime: 14.5 s

Total migration time: 165 s
Average VM downtime: 3.9 s
Average VN downtime: 13.7 s

25% improvement
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Problem Formulation

- The VM Migration Sequencing Problem can be formulated as an ILP
- **Objective function**

\[
\min \left( \sum_{t=0}^{T} w^t + \delta \sum_{i=1}^{I} \sum_{n \in N^i} X_{nt}^i P_n^i \right)
\]

minimize Migration time & Service down-time

- Where
  - \( T \) is maximum allowable migration time
  - \( w^t \) represents whether migration occurs at time \( t \)
  - \( I \) is the number of VNs
  - \( N^i \) is the set of VMs present in VN \( i \)
  - \( X_{nt}^i \) indicate whether \( n \) is under migration at time \( t \)
  - \( P_n^i \) represent the penalty (service downtime)
Problem Formulation

• Constraints
  • Only a single migration takes place for a single VM at any time instance
  • After a migration starts it cannot pause before completing
  • When a VM is under migration, it must be present in both the source and the destination
  • During the whole migration process capacity constraints for CPU, memory and disk must be satisfied.

• This problem generalizes the “Data Migration Problem” and hence it is *NP-Hard*. 
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Proposed Heuristic

- Finding the migration sequence
  - Step 1: Find feasible migrations
  - Step 2: Group them in RIGs
  - Step 3: Compute migration cost
  - Step 4: Select the RIG to be migrated
Step 1: Find feasible migrations

- Take all the VMs that can be migrated at the current time

Green: feasible
Red: infeasible
Step 2: Group them in RIGs

- Group them into Resource Independent Groups (RIGs)
  - VMs in the same RIG
    - Can be migrated simultaneously using disjoin paths
    - Does not have the same source or destination
Step 3: Compute migration cost

- Compute migration time, wait time and impact-on-other-RIGs
  - Migration time ($C_M$): max {migration time of any VMs in a RIG}
  - Wait time ($C_W$): the time the scheduler has to wait before making the next decision
  - Impact on other RIGs ($C_I$): increase/decrease in migration time of other RIGs
- Total migration cost, $C_T = \alpha C_M + \beta C_W + \gamma C_I$
Step 4: Select the RIG to be migrated

- Select the RIG with the lowest $C_T$ for migration at current time
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Evaluation Results

- We generated 4 deployment scenarios

<table>
<thead>
<tr>
<th>Scenarios</th>
<th># of VNs</th>
<th>Initial mapping</th>
<th>Target mapping</th>
<th># of Migrations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Active Phy. Hosts</td>
<td>Active Phy. Links</td>
<td>Active Phy. Hosts</td>
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<tr>
<td>$S - 1$</td>
<td>3</td>
<td>13</td>
<td>57</td>
<td>3</td>
</tr>
<tr>
<td>$S - 2$</td>
<td>10</td>
<td>95</td>
<td>307</td>
<td>14</td>
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<tr>
<td>$S - 3$</td>
<td>50</td>
<td>485</td>
<td>1483</td>
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<td>$S - 4$</td>
<td>100</td>
<td>935</td>
<td>2668</td>
<td>150</td>
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</tbody>
</table>

- VM specifications (CPU and memory) are taken from Amazon EC2 instances
- Bandwidth of virtual links are selected randomly between 250 and 750 Mbps
Evaluation Results

• We compare the performance of CQNCR with a baseline algorithm that
  • Chooses the VM with the shortest migration time first
  • Migrates multiple VMs simultaneously
  • Performs migrations using disjoint paths

• We compare the performance of CQNCR with the Baseline using 3 metrics
  • Total migration time
  • VM downtime
  • VN downtime (service disruption time)
Evaluation Results

- Total migration time

- CQNCR provides 35% improvement over the Baseline algorithm
Evaluation Results

• VM downtime

• CQNCR reduces VM downtime by up to 60%
Evaluation Results

- Virtual Network downtime

- CQNCR reduces VN downtime by up to 60%.
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Conclusion

• VM migration sequencing is an important problem as it has a direct impact on
  • Resource utilization
  • Service performance

• We proposed CQNCR for VM Migration Planning in Cloud data centers

• Benefits
  • Avoids network congestion
  • Reduce total migration time by up to 35%
  • Reduces VM/VN downtime by up to 60%
Future Work

- Assigning different priorities to different VNs
- Guarantee an upper bound on service downtime
- Consider the topology and workload of the VNs
Questions?
Backup Slides
Migration Graph & Infeasible Cycles

- Initial and final mappings

<table>
<thead>
<tr>
<th>Virtual Machine</th>
<th>Physical Machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>VM1</td>
<td>P4</td>
</tr>
<tr>
<td>VM2</td>
<td>P3</td>
</tr>
<tr>
<td>VM3</td>
<td>P2</td>
</tr>
<tr>
<td>VM4</td>
<td>P2</td>
</tr>
<tr>
<td>VM5</td>
<td>P5</td>
</tr>
<tr>
<td>VM6</td>
<td>P1</td>
</tr>
</tbody>
</table>

Initial Mapping

<table>
<thead>
<tr>
<th>Virtual Machine</th>
<th>Physical Machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>VM1</td>
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<tr>
<td>VM2</td>
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<td>VM3</td>
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<td>VM4</td>
<td>P4</td>
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<tr>
<td>VM5</td>
<td>P3</td>
</tr>
<tr>
<td>VM6</td>
<td>P4</td>
</tr>
</tbody>
</table>

Final Mapping
Migration Graph & Infeasible Cycles

- Migration graph
Migration Graph & Infeasible Cycles

- Infeasible cycle
Migration Graph & Infeasible Cycles

- Breaking cycle with *pivot node*

![Diagram of a migration graph showing infeasible cycles between nodes P1, P2, P3, P4, P5, P6, VM1, VM2, VM3, VM4, VM5, VM6.]
Evaluation Results

- VM specifications are taken from Amazon EC2 instances

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<thead>
<tr>
<th>EC2 Instance Type</th>
<th>vCPU</th>
<th>Memory (GB)</th>
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<td>m3.xlarge</td>
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<tr>
<td>m3.2xlarge</td>
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<td>30</td>
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<tr>
<td>m1.small</td>
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<td>7.5</td>
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<tr>
<td>m1.xlarge</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>c3.large</td>
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<td>3.75</td>
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<tr>
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<td>15</td>
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<td>7</td>
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<tr>
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<tr>
<td>cg1.4xlarge</td>
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<td>22.5</td>
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<tr>
<td>m2.xlarge</td>
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<td>17.1</td>
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