Subgraph Matching for Resource Allocation in the Federated Cloud Environment

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June 27, 2015
Outline

1. Introduction
2. Problem Modeling
   - Topology Modeling
   - Bandwidth Modeling
   - Cost Modeling
3. TBM Algorithm
4. Evaluation
   - Experimental Setup
   - Results
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Geo-Distributed Clusters

- **Opportunities:**
  - Available mechanisms and policies such as *Federated Cloud*;
  - Very high speed inter-DC communication technologies such as *optical fiber*;
  - Programming models that minimize size of data flow between nodes such as *MapReduce*

- **Advantages:**
  - fault tolerance
  - vendor independence
  - closer proximity to user base
  - cost benefits
Geo-Distributed Clusters

- Risks (regarding VM placement):
  - Cooperating VMs on distant DCs;
  - Clusters far away from their user base;
  - VMs placed without considering different pricing strategies of vendors

- Our Objectives:
  - To decrease **communication delay** (by placing connected VMs to the neighbour data centers)
  - To decrease **deployment delay** (by placing VMs close to the broker)
  - To reduce **resource costs** (by balancing load and avoiding overload in any DC)
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Topology Modeling

- Weighted, undirected, simple graphs
- Vertices represent cloud data centers / requested VMs.
  - CPU, Memory, Storage
- Edges represent the network connections between them.
  - Bandwidth, Latency
- Brokers represent the user base at each node
Bandwidth Modeling

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Cost Modeling

1. Fixed pricing based on memory, bandwidth and duration.
2. Dynamic pricing via Yield management
   - Increase the price of the resource that is running low in a DC
   - $\text{Cost} = \text{minCost} + (\text{maxCost} - \text{minCost}) \times \text{Util}$
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Topology Based Matching

1. Fetch VM Cluster
2. Find all isomorphic subgraphs
3. At least 1 subgraph exists
4. Select the subgraph with least latency
5. Submit VMs to matching DCs
6. Deploy VM
7. Terminate VMs
8. Submit Tasks
9. All VMs deployed
10. probe the next closest DC to VMs
11. probe the next closest DC to user
12. Fetch next VM
13. At least 1 VM is deployed
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Experimental Setup

Number of Clusters  Based on the population density around each location.

Number of VMs  Based on Poisson distribution: $\lambda = 3$

Cluster Topologies  Either linear or complete

Arrival Times  Uniform random in the range [0, 50)
Latencies

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Duration and Throughput

**Graph 1:** Task Completion Time (Hours) vs. VM RAM

**Graph 2:** Throughput (MIPS) vs. VM RAM

- ANF
- LBG
- RAN
- TBF
- LNF

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Rejection Rate and Cost

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Thank you for your attention.

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Appendix

Subgraph Matching
Future Work
More Results

Appendix

- Subgraph Matching
- Future Work
- More Results
Subgraph Matching

- Search space is all possible injective matchings from the set of pattern nodes to the set of target nodes.
- Systematically explore the search space:
  - Start from an empty matching
  - Extend the partial matching by matching a non matched pattern node to a non matched target node
  - Backtrack if some edges are not matched
  - Repeat until all pattern nodes are matched (success) or all matchings are already explored (fail).
- Filters are necessary to reduce the search space by pruning branches that do not contain solutions.
Algorithm 1. LAD-filtering

Input: A set $S$ of couples of pattern/target nodes to be filtered

Output: failure (if an inconsistency is detected) or success

In case of success, domains are filtered so that $\forall u \in N_p, \forall v \in D_u$, there exists a matching of $G_{(u,v)}$ that covers $\text{adj}(u)$.

while $S \neq \emptyset$ do
  Remove a couple of pattern/target nodes $(u, v)$ from $S$
  if there does not exist a matching of $G_{(u,v)}$ that covers $\text{adj}(u)$ then
    Remove $v$ from $D_u$
    if $D_u = \emptyset$ then return failure
  $S \leftarrow S \cup \{(u', v') \mid u' \in \text{adj}(u), v' \in \text{adj}(v) \cap D_u\}$

return success
LAD Filtering

Pattern graph $G_p$

Target graph $G_t$

\[
D_1 = D_3 = D_5 = D_6 = A, B, C, D, E, F, G
\]

\[
D_2 = D_4 = A, B, D
\]
Future Work

- **Algorithm**
  - Additional constraints (jurisdiction, partially known topology)
  - Vertical scaling support
  - Hybrid cloud support
  - Homeomorphism
  - Connected components

- **Evaluation**
  - Significance study
  - Evaluation with topology improvements
  - Multi-objective optimization
  - Dynamic heuristic selection, meta-heuristics
Link bandwidth request

<table>
<thead>
<tr>
<th>VM Communication Latency (Seconds)</th>
<th>Link BW</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANF</td>
<td>LBG</td>
</tr>
<tr>
<td>RAN</td>
<td>TBF</td>
</tr>
<tr>
<td>LNF</td>
<td></td>
</tr>
</tbody>
</table>

Cost ($)

<table>
<thead>
<tr>
<th>Cost ($)</th>
<th>Link BW</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANF</td>
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Minimum number of requests

![Graph showing throughput vs. number of requests for different algorithms: ANF, LBG, RAN, TBF, LNF. The x-axis represents the number of requests ranging from 1 to 8, and the y-axis represents throughput in MIPS.]
VM network intensity

![Graph showing task completion time and network intensity](image)

![Graph showing cost and network intensity](image)

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