Improving IaaS Cloud Analyses by Black-Box Resource Demand Modeling

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Modeling Resource Demands of Applications

- Classical Palladio component-based application models
  - Resource demand per action
  - Resource demands issued on resources based on user calls

- Influence of other load on the same resource, e.g. Virtual Machines (VMs)?
  - Infrastructure as a Service (IaaS): User interactions not monitorable
  - But: Monitoring of resource demand on hypervisor layer possible
    - Performance counters
    - (Potentially) system traces

→ Describe resource demand of VM as function $P(t)$ over time
Use cases

- Capture-replay of black-box VM resource profiles
  - What-if analyses for data center planning
  - Reasoning on the impact of placement and optimisation decisions on
    - Resource utilization
    - Energy consumption

- Modeling of performance interferences in virtualized environments

<table>
<thead>
<tr>
<th>Resource Share</th>
<th>Ideal: Fixed Share</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>VM A</td>
<td>Media Store</td>
<td>VM B</td>
</tr>
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</tbody>
</table>

Motivation ➔ Foundations ➔ Extending Usage Evolution ➔ Modeling Black-Box VMs ➔ Mapping to PCM+SimuLizar

14.11.2015

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Foundations – SimuLizar

SimuLizar [Becker2013a, Becker2013b]
- Set of extensions to core Palladio [Becker2009]
- Modeling and analysis of self-adaptive software systems

- Supports
  - Design and evaluation of self-adaptation strategies
  - Modular extension of evaluated system characteristics
  - Variances in usage profiles: **Usage Evolution** [Lehrig2015]
Foundations – Usage Evolution

- Model variations in user load and behavior over time [Lehrig2015]
  1. User load described in terms of
     - Interarrival time (open workload)
     - Number of concurrent users (closed workload)
  2. User behavior: Change value assigned to VariableCharacterisation
- Descartes Load Intensity Model (DLIM) [Kistowski2015] used to describe variations in (1) and (2)
Relaxing Assumptions for Usage Evolution

Usage Evolution made the following Assumptions and Limitations

A1) The evolution has the maximum simulation time as its only stop condition
A2) The evolution model's length of each Usage Scenario is less than or equal to the simulation time
L1) The evolution duration is always scaled to the maximum simulation time
L2) Only the first Usage Scenario is evolved
Relaxing Assumptions for Usage Evolution

A1) The evolution has the maximum simulation time as its only stop condition
A2) The evolution model's length of each Usage Scenario is less than or equal to the simulation time
L1) The evolution duration is always scaled to the maximum simulation time

→ Decoupling of evolution duration and simulation time
  - Specification of evolution sampling rate
  - Specification of (non-)repeating evolution interval
Modeling the Behavior of Black-Box Virtual Machines

- Workload description extracted from deployment environment
- Runtime measurements
- How to transfer to prediction models?

### CPU Workload

- Utilization in %

### HDD Read Workload

- MB/s

### HDD Write Workload

- MB/s
Modeling the Behavior of Black-Box Virtual Machines

![CPU Workload](image1.png)

![HDD Read Workload](image2.png)

![HDD Write Workload](image3.png)

**CPU Resource Demand**

**HDD Resource Demand**

Initially inferred for

Server A

<table>
<thead>
<tr>
<th>CPU</th>
<th>HDD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource Demand/s: $2.9 \times 10^9$</td>
<td>Resource Demand/s: $20 \times 10^6$</td>
</tr>
<tr>
<td>#Cores: 16</td>
<td></td>
</tr>
</tbody>
</table>
Modeling the Behavior of Black-Box Virtual Machines

CPU Workload

Utilization in %

HDD Read Workload

MB/s

HDD Write Workload

MB/s

inferred based on

Runtime Prediction

CPU Resource Demand

HDD Resource Demand

initially inferred for

<<BlackBox>> VM A

deployed on

Server A

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</thead>
<tbody>
<tr>
<td>Resource Demand/s: 2.9·10⁹ #Cores: 16</td>
<td>Resource Demand/s: 20·10⁶</td>
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Server B

<table>
<thead>
<tr>
<th>CPU</th>
<th>HDD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource Demand/s: 3.2·10⁹ #Cores: 16</td>
<td>Resource Demand/s: 14·10⁶</td>
</tr>
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</table>
Simulation of Black-Box Virtual Machines

- Black-Box VMs are not first-level entities in PCM
- But: Can be mapped to Core PCM + Usage Evolution
- Mapping realized as refinement transformation
  - CACTOS-specific transformation
  - Transformation for light-weight PCM extension

- Modeling of black-box VMs supported via MDSD Profile [Kramer2012]

- Simulation of refined model via SimuLizar
Mapping of Black-Box Models to SimuLizar and PCM

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**Motivation**

- Extending Usage Evolution
- Foundational Modeling of Black-Box VMs
- Mapping to PCM+SimuLizar

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**Improving IaaS Cloud Analyses by Black-Box Resource Demand Modeling**

- **Usage Evolution Model**
  - Usage Evolve VM A
  - Workload Parameter Evolution CPU
  - Workload Parameter Evolution HDD

- **System**
  - CPU
    - Work units per second: $3.2 \times 10^9$
    - #Cores: 16
  - HDD
    - Work units per second: $14 \times 10^6$

- **Architecture**
  - **Usage Model**
    - Usage Scenario VM A
      - Transmits Resource Demand
      - Translates specific VM A
      - Deployed on Server B

- **Black-Box Extension**
  - CPU Resource Demand
  - HDD Resource Demand
  - Mapped to <<BlackBox>> VM A
Mapping of Black-Box Models to SimuLizar and PCM

Motivation  Foundations  Extending Usage Evolution  Modeling Black-Box VMs  Mapping to PCM+SimuLizar

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Mapping – Example

- Repository – VM Component Specification

![Diagram showing VM A and its resource demand mapping to a Black-Box VM interface.](image)

Issued Demand
Mapping – Example

- VM Component Specification – Service Effect Specification (SEFF)

Issued Demand (specific per resource)
Mapping – Example

- **Usage Model**

- **Usage Evolution**

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Overview

Summary

• Extension to SimuLizar's Usage Evolution to support complex user behavior patterns
• Behavior of black-box VMs captured as load curves
• Mapping of black-box VM behavior model to PCM + Usage Evolution

Application scenarios

• What-if-analyses in an IaaS data center environment
• Modeling resource contention in virtualized environment with limited monitoring data

Future work

• Integration over DLIM curves instead of sampling
• Improved handling of delayed start and early termination of Usage Evolutions
References (1)


References (2)

