Service Placement in Network-aware Cloud Infrastructures

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Agenda

Motivation
• Can the Cloud host telecommunication services?
• Integrated infrastructure

Service and infrastructure model

Service placement
• Algorithms
• Evaluation methodology

Results

Conclusion
Motivation

Telecommunication service requirements

Maximal network delay guarantees / Maximal response time guarantees

- Due to
  - Interactivity
  - State lookup
  - Data synchronization
→ Particular locations of components
→ Specialized components
→ Replicated components

Bandwidth guarantees

- Due to
  - Stream transfers
  - Large content transfers
→ Particular locations of components
→ Specialized components
Motivation

Telecommunication service requirements

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Motivation

Telecommunication services in the Cloud?

Cloud = Infrastructure as a Service Cloud

Decoupling of
- Service Provider is customer of
- Resource Infrastructure Provider (Cloud Provider)

Components
- Loosely coupled
- Placement / location not relevant
- Usually one location
  - Sufficient bandwidth
  - Low inter-component delay

No Network View
→ No delay guarantees
→ No bandwidth guarantees
Motivation

IMS – Another real world telecommunication service

Motivation

Integrated Infrastructure and Network

BMBF Project MAMS/MAMSplus

• Simple communication service creation and execution environment for non-experts
• …, Intelligent Service Oriented Network Infrastructure, …
• Concepts and prototype

Service AND resource management

Integrated view of services, infrastructure, and network necessary
Model

Service Description
Model

Service Description

Component Functionality Description
Type with functional configuration
→ Node resource requirements
Model

Service Description

Component Functionality Description
Type with functional configuration
→ Node resource requirements

Channel Description
Link dependent communication channel requirements
– Bandwidth
– Delay
<WiSC uri="instance1" type="functional">
  <endpoint>10.0.1.1</endpoint>
  <protocol name="SuperVideoHeadEnd"
    version="1.0"
    contextType="Iptv">
    <methodProfile>standard</methodProfile>
  </protocol>
  <argument ref="VoDContent"
    unit="M">
    <value>10</value>
  </argument>
  <argument ref="LiveContent">
    <value>2000</value>
  </argument>
</WiSC>

<serviceLink uri="link1" type="bidirectional">
  <endpoint>10.0.1.1</endpoint>
  <endpoint>10.0.1.2</endpoint>
  <resourceRequirement uri="1">
    <ofClass ref="link/bidirectional" />
    <capacity ref="bandwidth"
      unit="Mbps">
      <value>300</value>
    </capacity>
    <specialProperty ref="delay"
      unit="ms">
      <maxvalue>200</maxvalue>
    </specialProperty>
  </resourceRequirement>
</serviceLink>
Model

Service Description

Access Description
Preferred location

Component Functionality Description
Type with functional configuration → Node resource requirements

Channel Description
Link dependent communication channel requirements
- Bandwidth
- Delay
Model

Service Description

Access Description
Preferred location

Component Functionality Description
Type with functional configuration
→ Node resource requirements

Delay Description
Over several components

Channel Description
Link dependent communication channel requirements
→ Bandwidth
→ Delay
Model

Resource Infrastructure / Network
Model

Resource Infrastructure / Network

**Node**
- Execution environment for components
- Arbitrary size
  - Host ↔ Computing Center
- Different resources
  - CPU, storage, DB functionality, …
- Internally installed bandwidth
Model

Resource Infrastructure / Network

Node
- Execution environment for components
- Arbitrary size
  - Host ↔ Computing Center
- Different resources
  - CPU, storage, DB functionality, …
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Link
- Installed bandwidth
- Delay
Model

Resource Infrastructure / Network

Node
- Execution environment for components
- Arbitrary size
  - Host ↔ Computing Center
- Different resources
  - CPU, storage, DB functionality, …
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Link
- Installed bandwidth
- Delay

Access Node
Entry and exit points to network
Model

Placement

Service Description

Instantiation Plan

Component Instance Connection

Resource Infrastructure / Network

Matching and Selection

Placement
Model

Placement

Service Description

Matching and Selection

Instantiation Plan

Placement

Resource Infrastructure / Network
### Placement

#### Strategies

<table>
<thead>
<tr>
<th>Type</th>
<th>RAND</th>
<th>NODE</th>
<th>TOP</th>
<th>OPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principle</td>
<td>Random</td>
<td>Greedy</td>
<td>Greedy</td>
<td>Optimal</td>
</tr>
<tr>
<td>Quality</td>
<td>Best</td>
<td>Uninformed worst</td>
<td>Topology-based (Service and Network inc. resources)</td>
<td>MILP (Mixed Integer Linear Program)</td>
</tr>
<tr>
<td>Complexity</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

- **Type**
  - Random
  - Greedy
  - Greedy
  - Optimal

- **Principle**
  - Uninformed
  - Node-based (Only Node resources)
  - Topology-based (Service and Network inc. resources)
  - MILP (Mixed Integer Linear Program)
Placement

Evaluation Methodology

Monte Carlo Simulation

- Independent samples with random service placed on random infrastructure/network
- Parameters
  - Allocated resources in infrastructure/network: 0% (Empty) ➔ 100% (Full)
  - Characteristic of service

<table>
<thead>
<tr>
<th>Topology</th>
<th>Centralized</th>
<th>Distributed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Resource Demand</td>
<td>Heavy-weight 80%</td>
<td>Light-weight 20%</td>
</tr>
</tbody>
</table>

Performance Metrics

- Ability: Fraction of non-placed services (Rejection)
- Quality: Comparison of total link bandwidth allocation w.r.t. OPT allocation
Results

Ability to Find Placement – Centralized, heavy-weight service

Centralized heavy-weight service

![Graph showing the relationship between available and allocated resources for centralized heavy-weight services.]
Results

Ability to Find Placement – Centralized, heavy-weight service

Centralized heavy-weight service

- Low optimization potential
Results

Ability to Find Placement – Centralized, heavy-weight service

Centralized heavy-weight service

- Low optimization potential
Results

Ability to Find Placement – Centralized, heavy-weight service

Centralized heavy-weight service

- Low optimization potential
- TOP close to OPT

→ Service- and network-topology matter
Results

Ability to Find Placement – Distributed, light-weight service

Distributed, light-weight service

- Significant observed differences in algorithmic behavior
- High optimization potential
  - Up to several orders of magnitude
  - Even between TOP and OPT

→ Service- and network-topology matter
→ Simple algorithms leave significant room for improvement
Results

Quality of Found Placement – PRELIMINARY RESULTS

Centralized, heavy-weight service
- TOP almost optimal

Distributed, light-weight service
- TOP with “acceptable” placements
  - If found!
- Behavior of NODE not yet understood
- Improved performance in high occupancy region due to few possible placements

Improvements without modification to routing!
Conclusion

- Current IaaS Clouds not prepared for telecommunication services
- Network view essential for channels between components and towards end-systems
  - Delay requirements
  - Required bandwidth guarantees
- Integrated view “Service/Infrastructure/Network” necessary for system management
  → Detailed model

- Placement of components has significant impact on
  - Number of running services
  - Bandwidth consumption
- Good placement algorithms must match service- and network-topology
  - Especially for distributed services
  - TOP leaves room for improvement