Towards negotiable SLA-based QoS Support for Data Services

ESSI Seminar

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Motivation for domain-specific data QoS
Quality of Service (QoS) – Service Level Objectives (SLOs)
QoS Model
QoS Negotiation and QoS SLAs
QoS Management in Data Mediation
Experimental Evaluation
Conclusions and future directions
QoS Scenario – Traditional Objectives

I want to pay less than 10 €, I can start simulation today at noon and I need the results by 3 pm

- Remote HPC facilities to be used by many different customers/clients
- Guaranteed **response times** and **price**
  - Resource reservation
  - Capacity/resource estimation
- Need to go beyond time and price guarantees: QoS in data services
Motivation – QoS on Biomedical Data

- **@neurIST project** – EU Integrated Project for the ‘Integrated Biomedical Informatics for the Management of Cerebral Aneurysms’
- **Service-oriented ICT infrastructure** providing
- **On-demand simulation, analysis and data-integration services**
- Handling **multi-scale, multi-modal** information at distributed resources

- Improve **decision making processes** by integrating all the available information to **identify at-risk patients** and reducing necessary treatment

- Support **computational design processes** towards a **next generation** of smart flow-correcting implants and reduce current treatment costs

- Support the **knowledge discovery for linking genetics to disease**, vasospasm and blood clotting after cerebral hemorrhage

- Support the **integration of modeling, simulation and visualization of multimodal data**
Data Mediation approach

- Data access and integration
- Virtualization of heterogeneous data sources as services
  - Hierarchical composition of data services
  - Integration of multiple data sources
  - Based on OGSA-DAI, de-facto standard for data access on the Grid
  - Distributed Query Processing (DQP)
- Data mediation services set up manually - Mapping Schemas
  - Large efforts required
  - Future semantic mediation …
Mapping Schema overview

- Global-as-View (GAV) mediation approach
  1. Definition of Global Schema
  2. Mapping rules between the global schema and the integrated schemas
Data Mediation Architecture

- Architecture of the Vienna Grid Environment (VGE)
- QoS Management for data - new
- Data Mediation Engine and Distributed Query Processing (DQP) run on a service hosting environment (Tomcat + Axis)
- Query Evaluation Services set up on several hosts (DQP)
- Data Sources to be integrated run on separated hosts
Data Mediation Practice

- Follows a **Best Effort** strategy for data services
  - Queries all services available
  - Applies mapping rules
  - Compiles result
- **Recall that “The Grid ...**
  - uses standard, open, general purpose protocols and interfaces
  - coordinates resources that are NOT subject to centralized control
    - delivers non-trivial qualities of service”
  
  *Foster, Kesselman (2002)*

- Explore the specificities of **Qualities of Service within Data Mediation Services**
  - Common requirement for advanced scientific applications
  - Defines path to **Business Model** for typical (scientific) usages
  - Experimentation using the VGE-based data mediation middleware
  - QoS Management prior to initiating data mediation and QDP
Usage of Data Grid Services

Virtualization of **distributed** and **heterogeneous data sources** as a large single **virtual database** (federation of data access)
Why QoS for Data in this Context?

- Data is fragmented
- Amount of relevant data
- Cost of data access
- Security/Privacy

Biomedical research use-cases

- Data mining (epidemiology)
- Content-Based Information Retrieval (decision support)
- Atlas generation (population variability)
## QoS Objectives → SLOs for Data

Adapt QoS management from computing services to data services.

<table>
<thead>
<tr>
<th>Service Level Objective (SLO)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>Price of query execution, based on pricing model (e.g. constant, function of result size)</td>
</tr>
<tr>
<td>Response Time</td>
<td>Guarantee response time to retrieve all results, depends on size of query result</td>
</tr>
<tr>
<td>Data Cardinality</td>
<td>Cardinality of total subjects (e.g. tuples) returned</td>
</tr>
<tr>
<td></td>
<td>Cardinality of reliable / quality (complete) subjects, or level of <em>constraints satisfaction</em> acceptable</td>
</tr>
<tr>
<td>Data Diversity</td>
<td>Maintain a certain diversity of data sources being queried (providers) – epidemiology</td>
</tr>
<tr>
<td>Data Locality</td>
<td>Specify the Locality of data access (legal constraints)</td>
</tr>
</tbody>
</table>
SLOs for Data: Monitoring

New SLOs require novel Monitoring – **SALMon** to identify degradation

- Identify Response Time degradation after SLA have been accepted
- Data-intensive scientific domains with QoS beyond response time
- Need to monitor the satisfaction of agreed SLAs for these other qualities of service
QoS Model for Data Services

- Client driven **QoS negotiation** with potential service providers
  - Client supplies: QoS requirements (e.g. **data quality**) and data request
- Request/Offer are **Web Service Level Agreements (WSLA)**
- Individual QoS Management for each service (and data source)

**Client Application**
- **QoS Negotiator**
- **Request**
  - `SELECT x,y,z FROM TABLE A,B,C WHERE CONDITION`
- **QoS**
  - `Card>100`
  - `Price < 1€`
  - `Diversity > 3`

**Service Provider 1**
- **WSLA offered**
  - `Card 150`
  - `Cost 0,6€`
  - `Diversity 4`

**Service Provider N**
- **WSLA offered**
  - `Card 200`
  - `Price: 0,8€`
  - `Diversity 5`
QoS Negotiation and WSLAs

- Negotiation follows (multiple rounds of) Request-Offer and finally a confirmation
- Based on Web Service Level Agreement (WSLA)
QoS Negotiation and WSLAs

```xml
<SLA xmlns="http://www.ibm.com/wsla" ... >
  <Parties>
    <ServiceConsumer> <!-- from certificate -->
      </ServiceConsumer>
  </Parties>
  <ServiceDefinition ... name="BioIS">
    <SLAParameter name="cost" ...>
    <SLAParameter name="cardinality" ...>
    <SLAParameter name="diversity" ...>
    ...  
    <!-- Metrics for each SLA parameter --> ...
  </ServiceDefinition>
  <Obligations>
    <ServiceLevelObjective name="cost"> ...
      <Expression><Predicate xsi:type="LessEqual">
        <SLAParameter>price</SLAParameter>
        <Value>1</Value> <!-- 1 Euro -->
      </Expression>
    <ServiceLevelObjective name="cardinality"> ...
      <Expression><Predicate xsi:type="GreaterEqual">
        <SLAParameter>cardinality</SLAParameter>
        <Value>100</Value> <!-- 100 result sets -->
      </Expression>
    <ServiceLevelObjective> <!-- other objectives --> ...
  </Obligations>
</SLA>
```
QoS Negotiation and WSLAs

```xml
<SLA xmlns="http://www.ibm.com/wsla" >
  <Parties>
    <ServiceConsumer>...
    <ServiceProvider>...
  </Parties>

  <ServiceDefinition name="BioIS_UPF">
    <SLAPrivateParameter name="cost" />
    <SLAPrivateParameter name="cardinality" />
    <SLAPrivateParameter name="diversity" />
    <!-- Metrics for each SLA parameter --> ...
    <WSDLFile>https://datanode.upf.edu/.../ds?wsdl ...
    <!-- Definition of service operations --> ...
  </ServiceDefinition>

  <Obligations>
    <ServiceLevelObjective name="cost"> ...
      <Expression><Predicate xsi:type="Equal">
        <SLAPrivateParameter>cost</SLAPrivateParameter>
        <Value>0,6</Value> <!-- 0,6 Euro -->
      </Expression>
    </ServiceLevelObjective>
    <ServiceLevelObjective name="cardinality"> ...
      <Expression><Predicate xsi:type="Equal">
        <SLAPrivateParameter>cardinality</SLAPrivateParameter>
        <Value>150</Value> <!-- 150 result sets -->
      </Expression>
    </ServiceLevelObjective>
    <!-- other objectives --> ...
  </Obligations>
</SLA>
```
QoS Aggregation of Federated Data Services

- Client aggregates QoS from several Data providers to meet SLO
- Data mediation/federation services aggregate QoS offers

### Scenario

<table>
<thead>
<tr>
<th>SLO</th>
<th>Satisfaction condition</th>
<th>Aggregation Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>≤</td>
<td>( \Sigma \text{cost}(\text{DAS}_i) )</td>
</tr>
<tr>
<td>Response time</td>
<td>≤</td>
<td>\text{max} \text{resp}(\text{DAS}_i)</td>
</tr>
<tr>
<td>Cardinality</td>
<td>≥</td>
<td>( \Sigma \text{card}(\text{DAS}_i) )</td>
</tr>
<tr>
<td>Diversity</td>
<td>≥/≠</td>
<td>( \Sigma \text{dive}(\text{DAS}_i) )</td>
</tr>
<tr>
<td>Locality</td>
<td>=</td>
<td>( \Lambda \text{loca}(\text{DAS}_i) )</td>
</tr>
</tbody>
</table>
QoS Management

- **Estimation model** predicts one or more SLOs
  Data source specific (relational DBs vs. PACs/DICOM images)
- Estimation Models may dependent on prediction of another model

**QoS request:** Set of SLOs

**QoS offer:** Set of SLOs
QoS Management

- Estimation Models may depend on prediction of another model → Challenge of orchestrating the models (direct acyclic graph of models)
  - Brute force: executing all permutations of models (<5 SLOs)
  - Topology sort to identify model invocation sequence (>5 SLOs)

- Conflicting objectives, cyclic dependencies - potential solutions:
  - Genetic algorithms
  - Mixed integer programming and linear programming (MIP/LP)
  - Answer set programming (ASP)
Experimental Evaluation

- Sample queries against @neurIST existing (best effort) data services
- Execute with QoS constraints (cardinality 50 or 100) and without constraints
- Measure query execution time

- Samples queries sorted by size of their results
- Ranging from:
  - Q1 few KBytes to
  - Q20 few MBytes

- QoS Support saves up to 60% query execution time
Experimental Evaluation (II)

- Compare gain with respect to ‘best effort’ query execution policy

- QoS guarantees the specified constraints (i.e. cardinality of results)
- But... QoS/100 can be worse... Thus efficient QoS Management and Negotiation remains challenging
Conclusions

- Domain driven QoS approach, tested in @neurIST sources
- QoS Negotiation
  - Request-Offer-Confirmation workflow
  - Aggregation of Service Level Objectives (SLOs)
- QoS Management
  - QoS Estimation Models
  - Different orchestration approaches
Future Work

- Identify synergies with Earth Observation applications (ESA, www.esa.int/esaEO) for SLOs for data services
- Evaluate guarantee of other data-SLOs (data diversity, quality, locality)
- QoS Support for more heterogenous data resources (different image modalities, simulation results/models, genetics, etc.)
- Investigation of more sophisticated QoS Mgmt models
  - Evaluate resolution of conflicting objectives
- Cloud infrastructure provision
Questions?

Thank You
The @neurIST Project

Integrated Biomedical Informatics for the Management of Cerebral Aneurysms

- Project duration: 2006-2010 (FP 6)
- 30 Partners
- Budget: ~17.5 MEuro

Objectives:

- Development of a generic IT infrastructure for the management & processing of heterogeneous data associated with the diagnosis & treatment of cerebral aneurysms.

- Transform the management of cerebral aneurysm by providing new insight, personalised risk assessment and methods for the design of improved medical devices and treatment protocols.
Motivation – QoS on Biomedical Data

Generic Processes:
- Obtaining relevant clinical information of patients (EHR - Electronic Health Record)
- Providing clinical decision support
- Offering simulation services
- Creating normalized population-based datasets
- Providing knowledge discovery services
- Compute power for simulations
- Patient data confidentiality
- Data access and integration