A Runtime Dependability Evaluation Framework for Fault Tolerant Web Services

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Outlines

1. Introduction
2. System Architecture
3. Methodology
4. Experiments
5. Conclusion
1.1 Web services

- Web service is becoming popular.
- Difficult to build reliable service-oriented systems
  - Internet and Web services are highly dynamic
  - Web service components are provided by different organizations
  - The compositional nature is hard to predict
1.2 Fault Tolerant Web Services

• Fault tolerant Web services by design diversity
  – Becomes less expensive, as the alternative components are available in the Internet
  – Requires adaptation, as the traditional fault tolerance strategies are too static

• Runtime evaluation on the target Web services

• Runtime proactive reconfiguration of the fault tolerance strategy
2 System Architecture
3.1 QoS of Web Services

• QoS offered by service provider:
  – Availability
  – Price
  – Popularity
  – Datasize

• QoS observed by service users:
  – Failure-rate
  – Response-time
  – Overall failure-rate
  – Overall response-time

\[ q = (q^1, ..., q^m), \]
3.2 Fault Tolerance Strategy

1) Time

2) Active

3) Passive

Table 1. Formula for FT Strategies

<table>
<thead>
<tr>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) ( r = 1 - \prod_{i=1}^{m} (1 - r_i) ); ( t = \left{ \begin{array}{ll} \min {T_{ij}} :</td>
</tr>
<tr>
<td>2) ( r = 1 - (1 - r_1)^m ; t = \sum_{i=1}^{m} t_i (1 - r_1)^{i-1} );</td>
</tr>
<tr>
<td>3) ( r = 1 - \prod_{k=1}^{m} (1 - r_k) ; t = \sum_{k=1}^{m} t_k (1 - r_k) );</td>
</tr>
<tr>
<td>4) ( r = 1 - (\prod_{i=1}^{m} (1 - r_i))^m ; t = \sum_{j=1}^{m} t_j (\prod_{i=j}^{m} (1 - r_i))^{j-1} ; t_i = \left{ \begin{array}{ll} \min {T_{ij}} :</td>
</tr>
<tr>
<td>5) ( r = 1 - \prod_{j=1}^{m} (1 - r_j)^m ; t = \left{ \begin{array}{ll} \min {T_{ij}} :</td>
</tr>
<tr>
<td>6) ( r = 1 - \prod_{j=1}^{m} (1 - r_j) ; t = \left{ \begin{array}{ll} \min {T_{ij}} :</td>
</tr>
<tr>
<td>7) ( r = 1 - (1 - r_1)^m ; t = \left{ \begin{array}{ll} \min {T_{ij}} :</td>
</tr>
<tr>
<td>8) ( r = 1 - (1 - r_1)^m ; t = \sum_{i=1}^{m} t_i (1 - r_i) \prod_{k=1}^{m} (1 - r_k) );</td>
</tr>
<tr>
<td>9) ( r = 1 - (\prod_{i=1}^{m} (1 - r_i))^m ; t = \sum_{j=1}^{m} (\sum_{i=1}^{m} t_i \prod_{k=1}^{m} (1 - r_k))^j - 2 ; )</td>
</tr>
</tbody>
</table>
3.3 Optimal Web Service Selection

• Method 1: rank target Web services by their overall QoS performance (OP)

\[ OP = \sum_{i=1}^{m} w_i \tilde{q}^i, \quad \tilde{q}^i = \frac{1}{n} \sum_{j=1}^{n} q^{i,j}, \]

• Weak point: new service users may not obtain similar performance
  – The network condition is different
  – The user geographic location is different
3.3 Optimal Web Service Selection

- Method 2: collaborative filtering algorithm
  - Similarity computation

\[
Sim(a, u) = \frac{\sum_{i \in I} (r_{a,i} - \bar{r}_a)(r_{u,i} - \bar{r}_u)}{\sqrt{\sum_{i \in I} (r_{a,i} - \bar{r}_a)^2} \sqrt{\sum_{i \in I} (r_{u,i} - \bar{r}_u)^2}},
\]

  - Similar user selection
  - QoS performance prediction

\[
P(r_{u,i}) = \bar{u} + \sum_{u_a \in S(u)} \frac{Sim'(u_a, u)(r_{u_a,i} - \bar{u}_a)}{\sum_{u_a \in S(u)} Sim'(u_a, u)}
\]

  - Optimal Web service selection
3.4 Dynamic FT Strategy Reconfiguration

• Update QoS performance of target Web service candidates dynamically.

• Update user requirements.
  – e.g., response-time < 1000 ms.
  – e.g., failure-rate < 5%.

• Dynamic optimal fault tolerance strategy determination
4.1 Experimental setup

- Prototype: [http://www.wsdream.net](http://www.wsdream.net)
  - Client: Java applet.
  - Server: Java servlet, MySQL
- Service users: CN, TW, AU, SG, HK, US
- Functionally equivalent Amazon Web services: a-us, a-jp, a-de, a-ca, a-fr, a-uk.

[http://ecs.amazonaws.com](http://ecs.amazonaws.com)
[http://ecs.amazonaws.jp](http://ecs.amazonaws.jp)
[http://ecs.amazonaws.de](http://ecs.amazonaws.de)
[http://ecs.amazonaws.ca](http://ecs.amazonaws.ca)
[http://ecs.amazonaws.fr](http://ecs.amazonaws.fr)
[http://ecs.amazonaws.co.uk](http://ecs.amazonaws.co.uk)
4.2 Evaluation of Individual WS

Table 2. Failure-rate of the Web Services

<table>
<thead>
<tr>
<th>WS</th>
<th>CN</th>
<th>TW</th>
<th>AU</th>
<th>SG</th>
<th>HK</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>a-us</td>
<td>22.52</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.38</td>
<td>0</td>
</tr>
<tr>
<td>a-jp</td>
<td>26.55</td>
<td>0.03</td>
<td>0</td>
<td>0</td>
<td>0.05</td>
<td>0</td>
</tr>
<tr>
<td>a-de</td>
<td>23.40</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.45</td>
<td>0</td>
</tr>
<tr>
<td>a-ca</td>
<td>24.23</td>
<td>0.19</td>
<td>0</td>
<td>0</td>
<td>0.58</td>
<td>0</td>
</tr>
<tr>
<td>a-fr</td>
<td>19.27</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.52</td>
<td>0</td>
</tr>
<tr>
<td>a-uk</td>
<td>20.28</td>
<td>0.03</td>
<td>0.25</td>
<td>0</td>
<td>3.87</td>
<td>0</td>
</tr>
</tbody>
</table>
### 4.3 Evaluation of FT Strategies

<table>
<thead>
<tr>
<th>Type</th>
<th>Cases</th>
<th>RTT(ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All</td>
<td>Fail</td>
</tr>
<tr>
<td>1</td>
<td>21556</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>22719</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>23040</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>21926</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>21926</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>21737</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>21737</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>21735</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>21808</td>
<td>0</td>
</tr>
</tbody>
</table>
5.1 Conclusion

- QoS of Web services
- Fault tolerance strategies
- Web service selection framework
- Proactive reconfiguration of optimal FT strategy