A Runtime Dependability Evaluation Framework for Fault Tolerant Web Services

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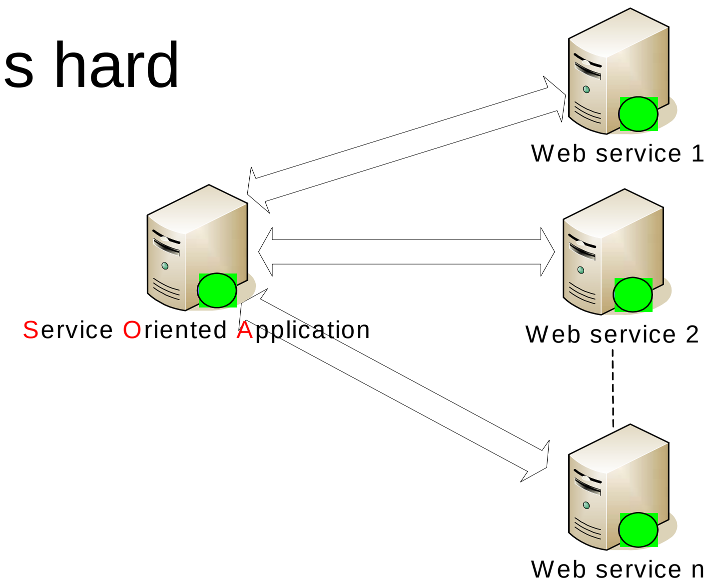
Outlines

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

1.1 Web services

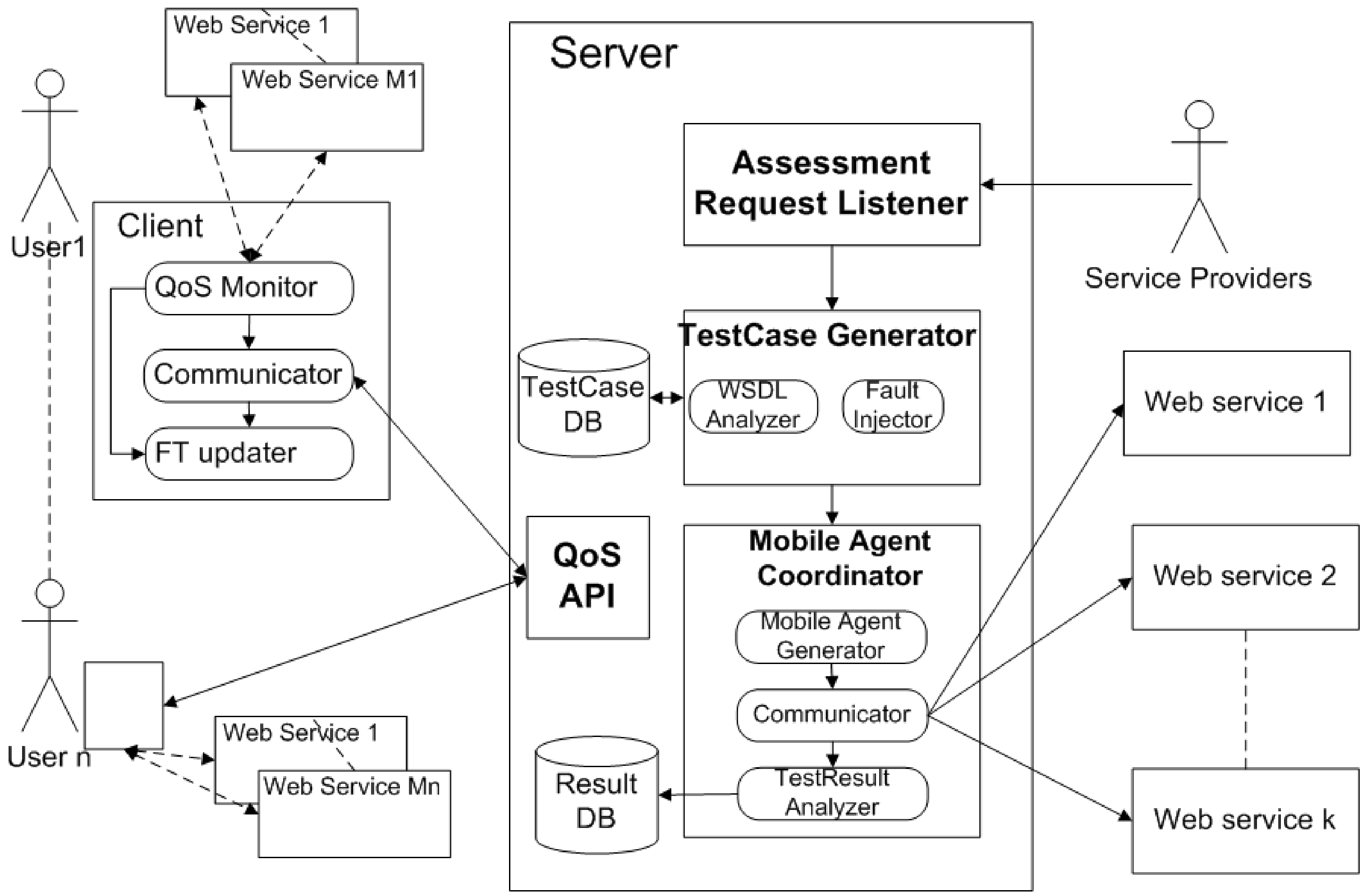
- Web service is becoming popular.
- Difficult to build reliable service-oriented systems
  - Internet and Web services are highly dynamic
  - Web service components are provided by different organizations
  - The compositional nature is hard to predict



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

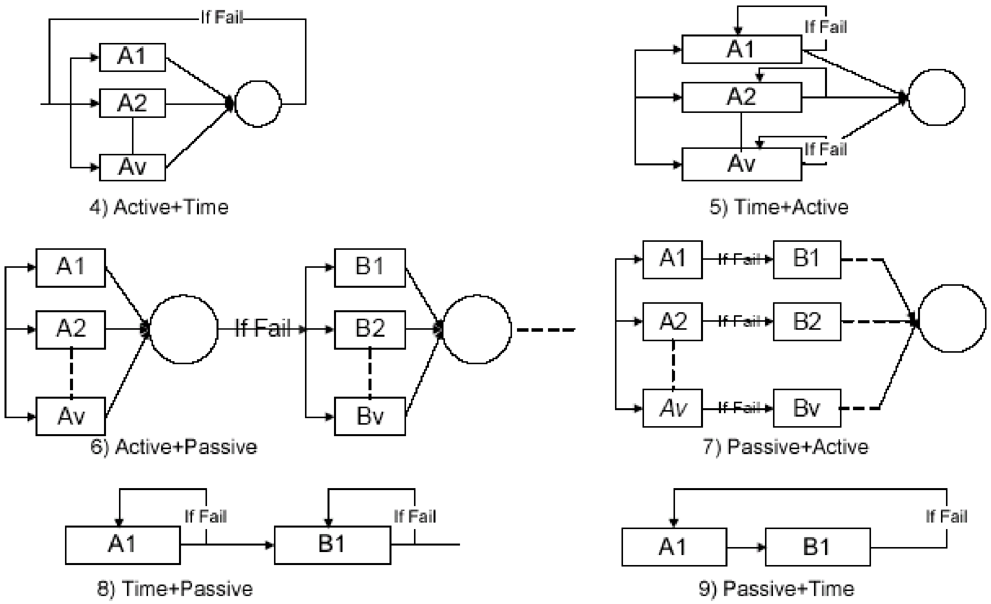


Table 1. Formula for FT Strategies

	Formula
1	$r = 1 - \prod_{i=1}^{n}(1 - r_i);$ $t = \begin{cases} \min\{T_c\} : \lvert T_c \rvert > 0 \\ \max\{T_f\} : \lvert T_c \rvert = 0 \end{cases} ; T = \{t_1, ..., t_n\} = T_c \cup T_f$
2	$r = 1 - (1 - r_1)^m; t = \sum_{i=1}^{m} t_i (1 - r_1)^{i-1};$
3	$r = 1 - \prod_{i=1}^{m}(1 - r_i); t = \sum_{i=1}^{m} t_i \prod_{k=1}^{i-1}(1 - r_k)$
4	$r = 1 - (\prod_{i=1}^{v}(1 - r_i))^m;$ $t = \sum_{i=1}^{m} t_i (\prod_{j=1}^{v}(1 - r_j))^{i-1}; t_i = \begin{cases} \min\{T_c^i\} : \lvert T_c^i \rvert > 0 \\ \max\{T_f^i\} : \lvert T_c^i \rvert = 0 \end{cases}$
5	$r = 1 - \prod_{i=1}^{v}(1 - r_i)^m;$ $t = \begin{cases} \min\{T_c\} : \lvert T_c \rvert > 0 \\ \max\{T_f\} : \lvert T_c \rvert = 0 \end{cases} ; t_i \in T = \sum_{j=1}^{m} t_{ij}(1 - r_i)^{j-1}$
6	$r = 1 - \prod_{i=1}^{m}\prod_{j=1}^{v}(1 - r_{ij});$ $t = \sum_{i=1}^{m} t_i \prod_{k=1}^{i-1}\prod_{j=1}^{v}(1 - r_{kj}); t_i = \begin{cases} \min\{T_c^i\} : \lvert T_c^i \rvert > 0 \\ \max\{T_f^i\} : \lvert T_c^i \rvert = 0 \end{cases}$
7	$r = 1 - \prod_{j=1}^{v}\prod_{i=1}^{m}(1 - r_{ij});$ $t = \begin{cases} \min\{T_c\} : \lvert T_c \rvert > 0 \\ \max\{T_f\} : \lvert T_c \rvert = 0 \end{cases} ; t_i = \sum_{j=1}^{m} t_{ij} \prod_{k=1}^{j-1}((1 - r_{ik})$
8	$r = 1 - \prod_{i=1}^{u}(1 - r_i)^m;$ $t = \sum_{i=1}^{u}((\sum_{j=1}^{m} t_i (1 - r_i)^{j-1}) \prod_{k=1}^{i-1}(1 - r_k)^m);$
9	$r = 1 - (\prod_{i=1}^{u}(1 - r_i))^m;$ $t = \sum_{i=1}^{m}((\sum_{j=1}^{u} t_j \prod_{k=1}^{j-1}(1 - r_k)(\prod_{j=1}^{u}(1 - r_j))^{i-1});$

3.3 Optimal Web Service Selection

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

$$OP = \sum_{i=1}^{m} w_i \tilde{q}^i, \qquad \tilde{q}^i = \frac{1}{n} \sum_{j=1}^{n} q^{ij},$$

- 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

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

  - Similar user selection
  - QoS performance prediction

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

  - 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
  - Zibin Zheng, Michael R. Lyu, “A QoS-Aware Fault Tolerant Middleware for Dependable Service Composition”, *in DSN2009*.

4.1 Experimental setup

- Prototype: 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.jp
http://ecs.amazonaws.de
http://ecs.amazonaws.ca
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4.2 Evaluation of Individual WS

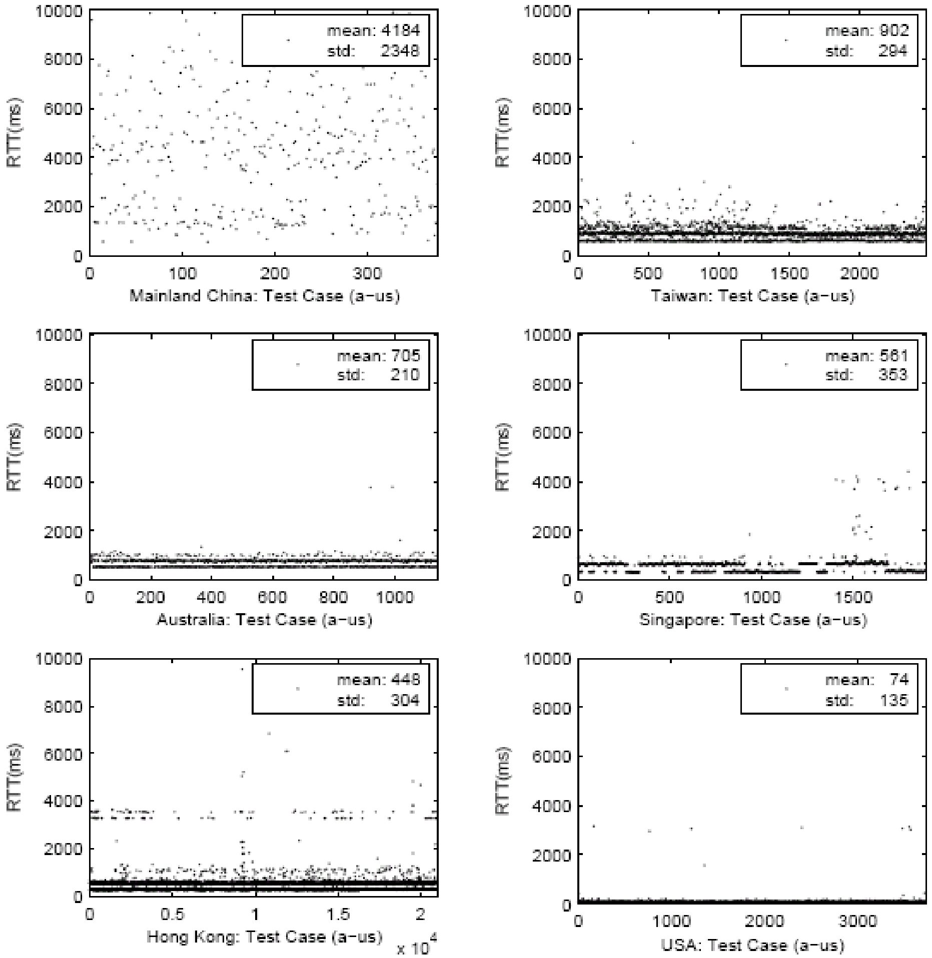

Table 2. Failure-rate of the Web Services

WS	CN	TW	AU	SG	HK	US
a-us	22.52	0	0	0	0.38	0
a-jp	26.55	0.03	0	0	0.05	0
a-de	23.40	0	0	0	3.45	0
a-ca	24.23	0.19	0	0	0.58	0
a-fr	19.27	0	0	0	3.52	0
a-uk	20.28	0.03	0.25	0	3.87	0

4.3 Evaluation of FT Strategies

Table 3. Evaluation of FT Strategies

Type	Cases			RTT(ms)			
	All	Fail	R%	Avg	Std	Min	Max
1	21556	6	0.027	279	153	203	3296
2	22719	0	0	389	333	203	17922
3	23040	0	0	374	299	203	8312
4	21926	4	0.018	311	278	203	10327
5	21926	1	0.004	312	209	203	10828
6	21737	2	0.009	311	225	203	10282
7	21737	2	0.009	310	240	203	13953
8	21735	0	0	411	1130	203	51687
9	21808	0	0	388	304	203	9360

5.1 Conclusion

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