CHAPTER 8

CONCLUSIONS AND FUTURE WORK

In this thesis, Tx-FAITH, a novel transactional framework is proposed to address the problem of reliable execution of hierarchically composed services involving long running transactions. As part of the TX-FAITH framework, an abstraction in terms of recoverability levels has been proposed for expressing the transactional properties of web services. The proposed recoverability levels are grouped in the increasing order of service recoverability and recovery costs. The recovery cost for different recovery mechanisms in case of service failure in compositions of various sizes has been measured and compared with the estimated recovery time. From the empirical analysis, it is proved that backward, cancellation, forward, and forward followed by cancellation recovery techniques incur costs in the ascending order. Hence, their grouping into recoverability levels in the increasing order is justified.

The second research issue that is addressed by TX-FAITH is the dynamic selection of services based on transactional properties, since it is a prerequisite to achieve reliable execution of compositions. Towards this, a template based model that interleaves the selection and execution steps is proposed in this thesis. The hybrid model - DILT- lends itself naturally for composing heterogeneous services. For a given pair of services with different transactional properties, the transactional property of their sequential as well as concurrent composition is determined and formally verified using a set of theorems. Using this result, the proposed selection approach determines
transactional requirements for each workflow activity based on business policies and recoverability levels so that it results in a reliable composition. This approach is user-friendly and is adaptive to the frequent changes in user requirements as well as business policies.

The runtime selection algorithm has been experimented for the vehicle purchase and registration system prototype and compared with its static selection counterpart. Though the runtime selection approach is found to incur an additional overhead in terms of execution effort that reduces the overall throughput, it is shown to be worthwhile for the advantages and flexibility it offers. This approach is suitable for B2B applications where the user preferences and business policies frequently change. The increase in the execution time is only marginal (34% increase), even when the number of available services is increased substantially (700%). Thus, the increased size of the workflow or service registry is found to have little impact on the time incurred for dynamic selection using the proposed approach. Moreover, it takes a total of 0.443 seconds only to select services, for all the 45 activities of a workflow from a registry containing 9000 services, with an average of 200 web services per activity.

An XML schema based approach is proposed for the specification of transactional service descriptions by integrating WSDL with WS-Policy. At run time, Tx-Selection middleware service discovers a suitable service for each workflow activity by comparing the functional and transactional requirements with the functional and transactional capabilities specified in Tx-WSDL documents of the service registry. If the transactional capabilities in the service descriptions cannot be provided during service execution, reliable execution of the composition cannot be achieved. Hence, transactional guarantees are included as SLAs and the transactional contracts are generated as soon as the service from a third party provider is selected. An approach is
proposed to extend WS-Agreement to include transactional agreements and dynamically generating such *Tx-Contracts*.

The third major research issue addressed by the transactional framework, Tx-FAITH involves transactional coordination of hierarchically composed business processes by exchanging context messages among workflows of different organizations. The hierarchical workflows may involve long-running as well as composite activities. For a failure tolerant execution of such workflows, Tx-FAITH includes a recovery protocol that applies an appropriate recovery mechanism based on the transactional properties of the failed service and the type of failure.

The proposed Tx-FAITH framework has been implemented and tested for VPRS prototype business application comprising of hierarchical workflows. The experimental results show that the number of requests processed per unit time is 1 request per 10 seconds, with 200 simultaneous users and a total database size of 0.35 million records which is a good response. The performance of VPRS prototype adapting Tx-FAITH framework was observed by enabling one type of recovery mechanism for all the failed or cancelled services. It is verified that the recovery time or cost incurred for different types of recovery mechanisms adopted by the recovery protocol of Tx-FAITH conforms to the recovery cost estimations.

### 8.1 RESEARCH CONTRIBUTIONS

The key contributions in this research are:

- Cancellation recovery of services due to external interruption of long running business processes
- Dynamic selection and composition of web services based on transactional properties to achieve reliable execution
o Specification of transactional capabilities along with service descriptions

o Automated generation of contracts with transactional guarantees

- Abstraction of transactional properties in terms of recoverability levels to capture transactional requirements

The summary of the research contributions is presented in Table 8.1.

8.2 FUTURE DIRECTIONS

The research work of this thesis has brought forth the following issues that need further investigation.

- Tx-FAITH framework supports cancellation recovery of long running services which involves compensating all the completed services (say i-l) prior to the cancelled service i. This involved an increased compensation cost as well as the execution cost of the completed services. Hence, an approach of conditional compensation can be evolved wherein only i-l to i-x, (x > 1) services need to be compensated and service execution resumes from i-xth service. With conditional compensation, the cancellation recovery cost of long running services would be reduced. An approach needs to be devised to specify compensation points similar to save points, based on business policies
<table>
<thead>
<tr>
<th>Research Issue Addressed</th>
<th>Disadvantages of Existing Work</th>
<th>Proposed Research Contribution</th>
<th>Advantages of Proposed Research Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Cancellability</td>
<td>Only internal cancellation of services</td>
<td><strong>Cancellation recovery</strong></td>
<td>Enables external interruption of services whenever user requirements change. Enables selection of cancelable long running services with minimum overhead.</td>
</tr>
<tr>
<td>Web Services Selection</td>
<td>Existing transaction aware design-time selection approach is based on only 4 types of TWS and it does not consider cancelable services. The selection approaches based on ATS require ATS to be manually specified. Correctness and adequacy of ATS are not guaranteed</td>
<td><strong>Transaction aware runtime service selection</strong></td>
<td>Results in reliable execution of the composed service. Considers 8 types of TWS including cancelable services</td>
</tr>
<tr>
<td>Difficulty in capturing transactional requirements</td>
<td>Abstractions do not relate to recovery efforts, which is important due to frequent failures in the Internet environment</td>
<td><strong>Recovery cost based recoverability abstraction for transactional properties</strong></td>
<td>Business analyst is better aware of the recovery cost while specifying the transactional requirements. It helps in finding functionally equivalent but behaviourally compatible alternate services.</td>
</tr>
<tr>
<td>Absence of Transactional capability in service description</td>
<td>Not addressed by any existing work</td>
<td><strong>Transactional web service descriptions</strong></td>
<td>Transactional requirements can be matched against transactional capabilities of services which enables transaction aware service selection</td>
</tr>
<tr>
<td>Transactional agreements in Contracts</td>
<td>Existing approaches do not extend WS standards with transactional guarantees</td>
<td><strong>Transactional Contracts generation</strong></td>
<td>Establishes trustworthiness of service providers and can be monitored for violations in agreements</td>
</tr>
<tr>
<td>Interactive specification of user requirements</td>
<td>Not supported in BPEL based frameworks</td>
<td><strong>Dynamic Interleaved Template Model for composition</strong></td>
<td>Enables flexible specification of requirements as and when the service is about to be composed. Since interruption is allowed, any time during execution of services they can be cancelled due to changes in user requirements. Enables integration of different types of services, such as SOAP based and RESTful services. Users can preserve the privacy of data and can avoid security risks.</td>
</tr>
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- Tx-FAITH framework involves dynamic selection of services based on the transactional requirements. When a suitable service with the required recoverability level is not available in the registry, a service with a higher recoverability level can be chosen if such a transactional property of the service results in a reliable execution. Hence, a discovery mechanism that selects alternate services with compatible transactional properties can be explored. However, a service with a better recoverability level would incur an additional cost.