ABSTRACT

With the emergence of Service Oriented Computing, business organizations adopt new ways of carrying out businesses. Web service composition has become a promising approach to meet the user demands, whenever a single service by itself cannot fulfill the needs. A composite service comprising of several component services can be viewed as a workflow. A composite service provider may implement only a few core functionalities, while outsourcing other functionalities. Some of these functionalities may be offered as composite services represented by a nested workflow. Coordination and execution of such hierarchically composed workflows gains importance in business applications.

In view of frequent failures in the internet environment where the composed services are executed, reliability of execution must be ensured to achieve consistent termination. Existing web service transaction models do not consider interoperable transactions and lack the ability to create advanced transactional frameworks to orchestrate cross-organizational heterogeneous transactions of collaborating business domains. Existing transactional frameworks for reliable execution of composite services consider only retrievable and compensatable services as well as their recovery. However, while achieving reliable execution, service cancellability is important due to the predominance of long running processes in business applications and
frequently changing user requirements and business policies. If the execution of a long running process is not cancelled in case of a changed requirement, the completion of the process results in wastage of resources and the outcome may no longer be useful. With this in mind, a novel transactional framework, namely **Tx-FAITH (Transactional Framework for FAIlure Tolerant execution of Hierarchical transactions across organizational boundaries)** that supports cancelable transactions and cancellation recovery to achieve reliable execution of composite services is proposed in this thesis. Tx-FAITH addresses the following research issues:

- Extraction of the transactional requirements from the business policies
- Transaction aware dynamic web service selection based on the requirements
- Coordination of hierarchically composed workflows by executing the selected services in a failure tolerant manner

In the context of the first research issue, after extracting the transactional requirements from the business policies, they must be matched with the capabilities of the services deployed in the registry, in order to enable transaction aware selection of services. However, it is difficult for a business analyst to envisage the desired business policies of a business process in terms of transactional properties of the corresponding service. Most of the existing works on specification of transactional properties require the business analyst to frame the rules or dependencies, which is rather cumbersome. Hence, an
abstract mechanism using recoverability of services that enables the business analyst to specify the transactional properties in a simple manner is proposed in Tx-FAITH framework. The gradation of recoverability levels based on recovery cost is derived and justified using an empirical analysis of recovery costs incurred for different recovery mechanisms.

The next research issue addressed by Tx-FAITH is the transaction aware web services selection. In business applications, the end-user would prefer to decide the service parameter values of the component services based on the outcome of the previous service execution. Existing works on dynamic composition assume that the user preferences are frozen at the starting of the execution of the composite service and none of the prevailing transaction aware selection approaches are dynamic. The proposed selection approach is dynamic and it also supports cancelable services in addition to the traditional categories of services such as pivot, retrievable and compensatable. The ability of the proposed selection approach to produce compositions that result in a reliable execution has been formally analyzed and verified. From the experimental evaluation, it is evident that the proposed selection approach takes only 443 milliseconds even with 9000 services in the registry. Further, the increase in the selection time is only marginal (34% increase), even when the number of services in the registry is increased substantially (700%).

The third research issue addressed by Tx-FAITH is the failure tolerant execution of services across organizational boundaries. The coordination of hierarchically composed workflows cannot be performed using the existing de facto standard Business Process Execution Language
(BPEL), as it does not support stateful communication which is essential across organizations. BPEL based composition is static and stateless, with rigid fault handling mechanisms. This inability is the motivation behind the proposal of a context based coordination approach with transactional recovery protocol that performs an appropriate recovery based on the transactional capability of the failed service and based on the kind of failure. Further, a cancellation recovery mechanism is also proposed in this thesis, to restore the service execution to a consistent state upon external cancellation of a long-running business process. The proposed coordination and recovery approach has been implemented and tested for a prototype e-Governance application comprising of hierarchical workflows. The experimental results show that, with 200 simultaneous users and with a database size of 0.35 million records, the proposed approach incurs a response time of only a few seconds, typically 10 seconds to process a single request.

In summary, the major contributions of this thesis are as follows:

a) An abstraction to express transactional requirements of web services  
b) Transaction-aware web services selection at run-time  
c) Cancellation recovery of long running business processes.

The proposed Tx-FAITH transactional framework is shown to have better features when compared with the existing frameworks.