INFORMATION DISCOVERY ACROSS ORGANIZATIONAL BOUNDARIES THROUGH LOCAL CACHING

By

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION

Web Service is a software system designed to support interoperable machine to machine interaction over a network. Web services are deployed within restricted spaces of organizations intranets. There is a need for the creation of virtual organizations where the services offered by one organization should become accessible to other organizations. It requires opening of IT infrastructures to its participants so that the information can flow easily within the virtual organization. The main goal of a Service-Oriented Architecture (SOA) is to bring the uses of loosely coupled systems and encapsulation to the integration process at an enterprise level. A service is the unit of work done by a service provider to achieve desired results for a service consumer. Web services standards and the SOA provide help toward opening IT infrastructures by providing a uniform way to expose the functionalities through standards like Web Service Description Language (WSDL) and Simple Object Access Protocol (SOAP), and to discover web services through standards like Universal Description Discovery and Integration (UDDI). A complete SOA implementation can be achieved with the help of an Enterprise Service Bus (ESB). The ESB is the infrastructure which supports a fully integrated and flexible end-to-end service-oriented architecture.

SOA specifies that every service that is registered with the available UDDI registries can be discovered and invoked. Hence the discovery of web services is limited to the scope of available UDDI registries. The service provider advertises about the type of services it offers to the registries, this process is known as registration. In order to extend the infrastructure for the creation of virtual organizations, the SOA must be extended across organizations. There are many different ways to allow web services be available to other partners within the virtual organization.

One way to extend SOA across organizations is to allow the web services to register with all the available UDDI registries of the other partners within the virtual organizations. Upon receiving a request the UDDI directly gives the details of the service provider to the client since every provider advertises with all the UDDIs. This is can be viewed as having a distributed environment of UDDIs. This solution is problematic because it leads to multiple copies of registrations across the virtual organization. Such a system has a number of disadvantages: first, every detail of the description of the web service should be maintained and updating all the copies of registration of web service whenever changes are made to it becomes difficult. It increases the traffic, which are the interactions between systems. Second, if a web service does not register with all the UDDIs within the virtual organization it may not be visible and discoverable.

Another sophisticated way is to make a web service register with only one UDDI, as it normally does and allow the UDDI registries to exchange information about the web services they have registered [7]. Then any application would inquiry only one UDDI.

Upon receiving the inquiry, the UDDI may solve it directly if it has the required information, or it may contact other UDDIs to find the requested service, and reports back to the client what it found. The difficulty of this solution is that UDDI registries should discover each other. The local registry has to query all the available UDDIs within the virtual organization about the service needed. The amount of queries increases polynomially with the increase of partners in the virtual organization.

In Extended Service-oriented architecture (ESOA), the virtual organization establishes a UDDI registry, called Main Registry, that collects the registrations of the partner registries and answers queries about which registry is more likely to contain a specified type of service [7]. In this model, whenever a local UDDI could not find information about the type of service requested, it only has to query the Main registry rather than all the UDDIs within the virtual organization. This reduces the number of queries placed. But the drawbacks of this model are: first, if for any reason there is a central point of failure, i.e., if the Main registry goes down then the situation comes back to the previous model where the local UDDI registry has to contact all the available UDDIs within the virtual organization. Second, if an application places a request for the type of service which was requested before by another application within the scope of same UDDI. The UDDI has to repeat the discovery process again by querying the Main registry. There are chances that the process will be repeated if many requests are placed for same kind of web service.

The proposed model is developed to resolve the issues of the above mentioned ESOA structure. The main aspect of this thesis is to develop an architectural model to support the creation of virtual organizations, and is called a Virtual Service-oriented Architecture (VSOA). VSOA is based on the observation that UDDI registries are themselves web services also. Hence it provides a way for the UDDIs to discover each other within a virtual organization. It extends ESOA by introducing a registry, called the Cache Registry locally within an organization that acts as a registry to support discovery of service providers belonging to different organizations and also contain details of the services offered. Like in ESOA, when a client places a request for a service and if the local UDDI does not have the required information, it queries the Main registry. And the results it gets from the Main registry are stored in the Cache registry locally. So whenever a service request is placed, first the requester queries the cache registry to check if it can provide the information about the provider of the placed request. Cache registry is updated each time a new service is requested by the consumer, along with the results it got from the providing organization.

CHAPTER II

LITERATURE REVIEW

2.1. Service-oriented Architecture

Service-oriented Architecture is an approach used to define integration architectures based on the concept of services. A Service-Oriented Architecture (SOA) is an architectural style whose goal is to achieve loose coupling among interacting software agents. Service-oriented architecture defines concepts and general techniques for designing, encapsulating, and invoking reusable business functions through loosely bound service interactions [1]. SOA presents an approach for building distributed systems that deliver application functionality as services to either end-user applications or other services. It is comprised of elements that can be categorized into functional and quality of service. In a SOA, services are given the highest importance. Services are defined by the independent interfaces. All services encapsulate reusable business functions and can be invoked using communication protocols. The encapsulation of services by interfaces and their invocation through interoperable protocols are the means by which SOA enables greater flexibility and reusability.

SOA identifies three stakeholders: the provider of the service, the requester of the service, and a registry, typically UDDI, that takes the responsibility of finding the best provider that matches the requirement of the requester. A detailed view of the basic protocol used within SOA [7] is shown in Figure 2.1.

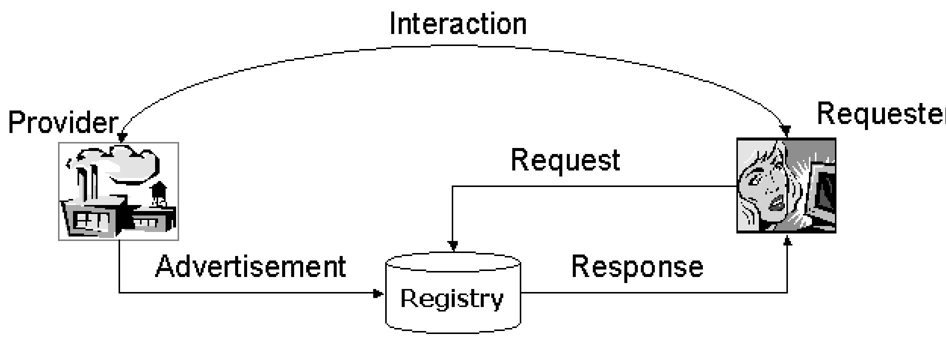


Figure 2.1: Basic Service Oriented Architecture

The service provider advertises with the registry by providing a description of the services it provides. Service descriptions are provided using the Web Services Description Language (WSDL) documents. WSDL is an XML based service description that describes the public interface, protocol bindings and message formats required to interact with a web service. The requester sends a request to the registry asking it to find the services which satisfies its set of requirements. The registry sends a report as a response to the requester with the details of the providers of the service that it found. Finally, the requester selects the best service for the task and starts interaction with the provider.

A SOA uses a web services as a communication mechanism with XML documents being routed over an Enterprise Service Bus. Existing host applications become service providers in a service-oriented architecture. The ESB will carry the XML-based documents and route them depending on the content. Routing and orchestration are the fundamental parts of an ESB along with other services like management, guaranteed delivery and security. Interoperability is the most important aspect of a SOA. Remote invocation is provided through Simple Object Access Protocol (SOAP), Web Services Description Language (WSDL) is used to describe the service interfaces and the services are discovered through the use of Universal Description Discovery and Integration (UDDI).

2.2. Enterprise Service Bus

The Enterprise Service Bus (ESB) enables an SOA by providing the connectivity layer between services. The ESB is primarily concerned with the program-to-program communications necessary to support services-oriented interactions and combines messaging, transformation, and content-based routing into a single product. The ESB can be designed according to the business process services of the company implementing it. Descriptions of the services available from a service provider can be accessed by the service requestors with the help of registry of services. In order to participate in ESB-managed interactions the service endpoints need to register with the ESB. The service providers publish the meta-data about their capabilities and services they offer and the service requestors publish the meta-data about the kind of information they are looking for. The ESB manages the meta-data through a registry, which supports configuration, connection, matchmaking and discovery of service endpoints. The meta-data describes service requestors and providers, mediations and their operations on the information that flows between requestors and providers, and the discovery, routing and matchmaking that takes place dynamically.

2.2.1. The role of ESB and other SOA components

The ESB is not the only infrastructure in SOA, there are other components whose role is to be positioned relative to the ESB [1]. The figure 2.2 shows the relationship between all the components.

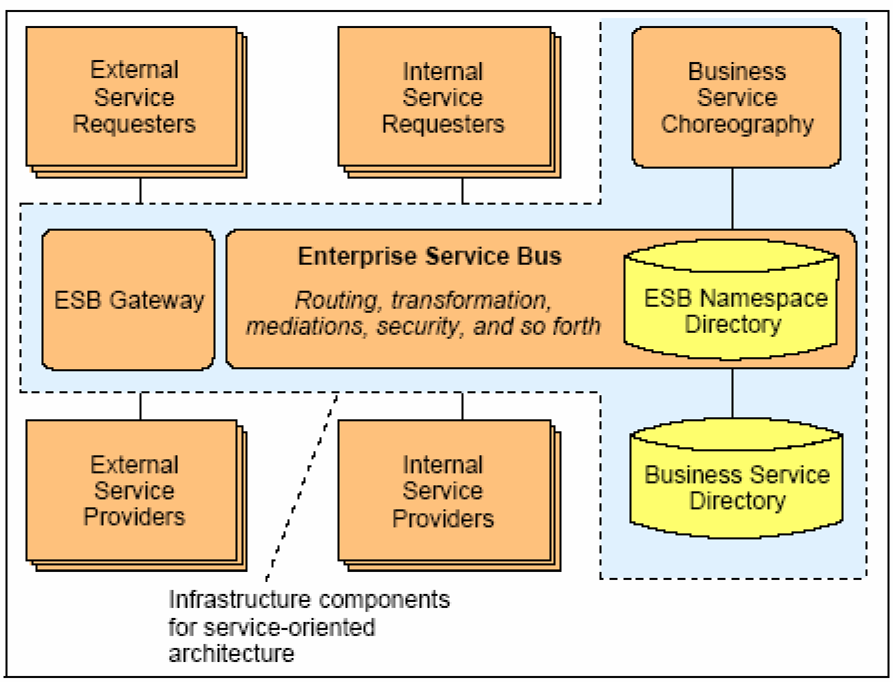


Figure 2.2: The role of the ESB in a SOA

- The Business Service Directory, which provides the details of the services available to the systems participating in the SOA. The main goal of the business service directory is to publish the availability of services and encourage their reuse by the development activity of an enterprise. The business service directory can be implemented as a design-time service catalogue or an open-standard Universal Description, Discovery and Integration UDDI directory that enables dynamic discovery and invocation of business services.
- ESB Namespace Directory, which provides the basic routing information by means of a routing table.
- The Business Service Choreography, which is used to orchestrate the sequences of service interactions. The role of choreography is to define and execute business processes, whose flows are determined by the business logic. Such kind of behavior is not part of the ESB, but ESB is responsible for functions that involve sequencing, mediations and other invocations of technical services around the invocations of business process.
- The ESB Gateway, which is used to provide a controlled point of external access to the services where the ESB does not provide it locally. Large organizations will keep the gateway as a separate component, which can also be used to federate ESBs within an enterprise. The ESB gateway makes the services of one organization available to others in a controlled and secure manner.

2.2.2. Emerging patterns for integrating different ESBs

Within an organization, the need to have different ESBs arises if they have different governance bodies, funding models, geography, different business strategies. The use of SOA techniques for integration is called Service Oriented Integration (SOI). These are three emerging patterns for ESB Topology [4].

- Directly connected ESBs pattern: This pattern is used to route messages between two ESBs. Service consumer of one ESB connects with the service provider of other ESB and the link is created between them. As a point-to-point topology, the endpoints contain the implementation knowledge of each other. For example, the ESB hosting service consumer must know which ESB hosts the service provider, what protocol to use to get the service done, and message format so it can route the request. This result in service routing rules distributed across multiple ESBs and in multiple ESB components. The consumer ESB should transform their messages so that the service provider understands the message and performs the operation.

  The problems faced in this model are: first, only two ESB can communicate at a time. Second, service provider location must be known to the service consumer before invoking it. Third, the number of links grows exponentially as the number of components being linked together grows. Maintenance will increase as the number of links between ESBs increases.

Fourth, all the service consumers will have to take the burden of transforming their messages according to the protocols used by external service providers.

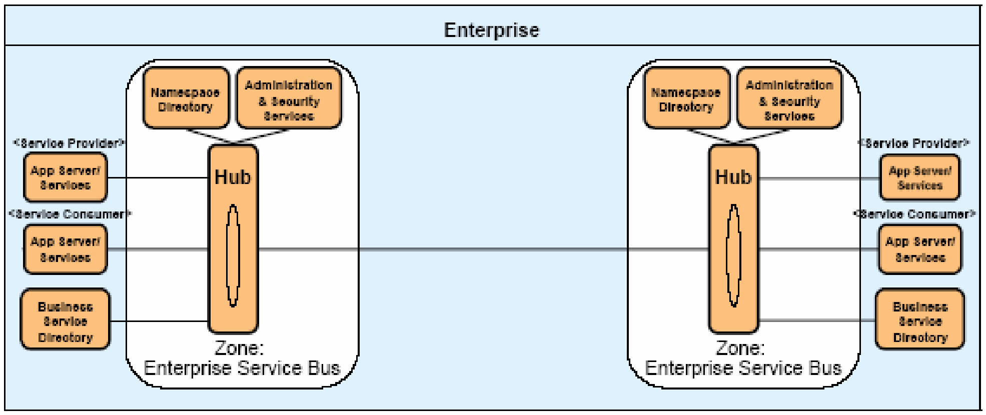


Figure 2.3: Directly connected ESBs Pattern [4].

- Brokered ESB Gateway pattern: The number of point-to-point connections can be reduced by introducing a centralized gateway between all the ESBs in an organization. It may be located in a different governance zone than any of the ESBs it integrates and may be under the control of a third party. This encapsulates the implementation details such as routing rules into the Gateway. Each ESB has less implementation knowledge of other ESBs. ESB Gateway often connects heterogeneous ESBs, adapts a wide range of standards and protocols. It has to mediate potentially incompatible standards.

The problems faced by this topology are: first, the gateway has the routing offer nothing more than a routing service. It does have any service providers connected to it. So it does not have a business service directory where all the information about a service provider is stored. Second, service provider location must be known to the service consumer before invoking it.

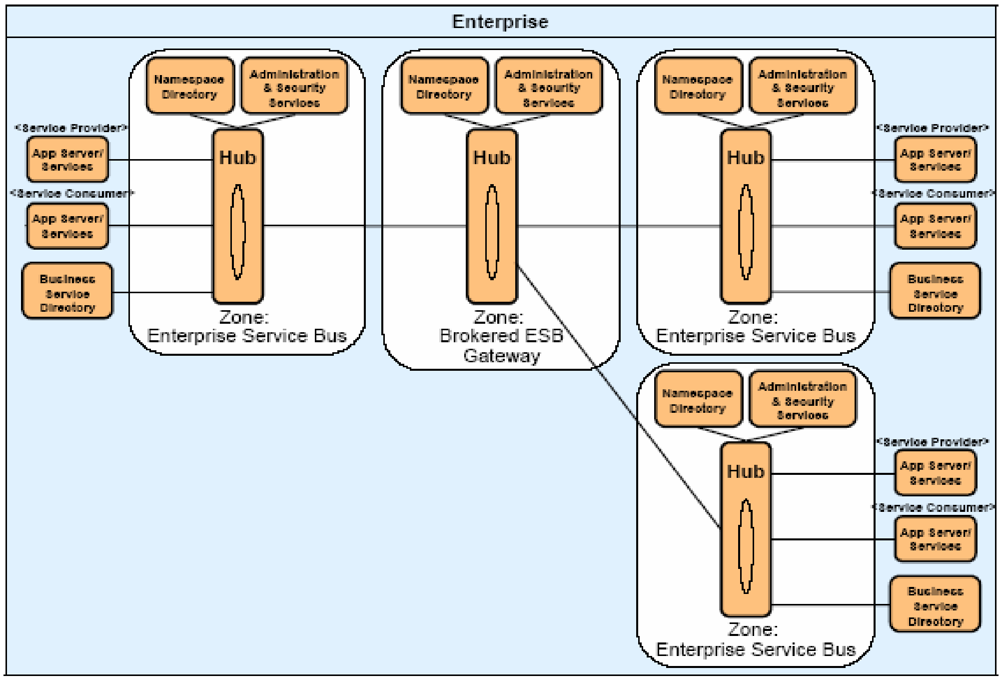


Figure 2.4: Brokered ESB Gateway Pattern

- Federated ESB pattern: This pattern is useful when resources are used from multiple providers in multiple ESBs. It adds orchestration of service requests that span multiple ESBs, multiple providers or both. The service consumer of the request gets the information of all the resources from different providers in all the ESBs, complete the request and sends the response.

The difficulties in this topology are: first, this option is a good choice if there are only one or two occurrences of such requirement. If there are more than two occurrences exist, this solution would lead to federation logic scattered across multiple ESBs [4]. This situation would be similar to the problem of directly connected ESBs, the penalty would be in the form of higher costs to maintain and extend the implementation. Secondly, If the services of two or more ESBs are fully federated i.e., all services are shared then by the definition of ESB, they become one larger ESB rather than separate ESBs.

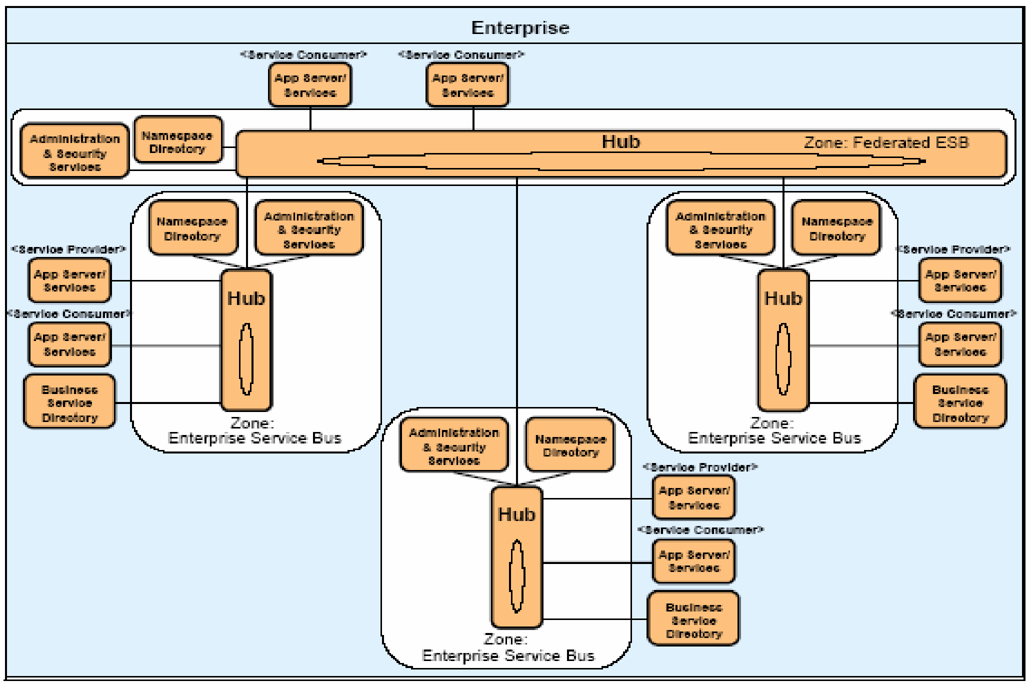


Figure 2-5: Federated ESB Pattern

2.3. Extended Service Oriented Architecture:

To support the need to make the services offered by one organization accessible to another, SOA needs to be extended to span across organizational boundaries. But according to SOA it is an implicit assumption that the discovery of web services is limited to the scope of the available UDDI registries. Here comes the

Extended Service Oriented Architecture model, where UDDIs are considered as web services themselves. In ESOA, the virtual organization establishes a UDDI registry, called Main Registry, that collects the registrations of the partners' registries and answer queries about which registry is more likely to contain a specified type of service [7].

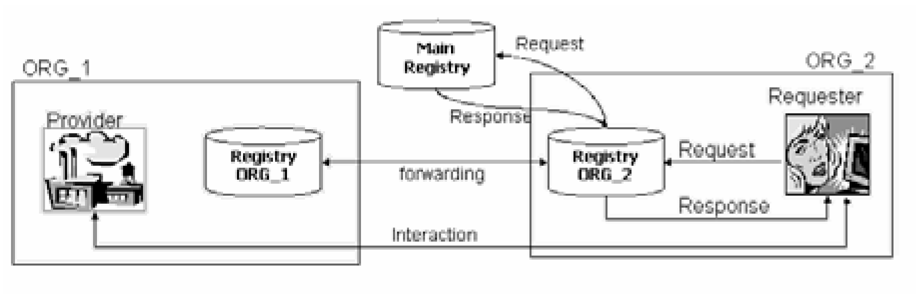


Figure 2.6: Extended SOA protocol

ESOA has four stakeholders: service requesters, service providers as in SOA. The third stakeholder is a set of registries that store advertisements of providers and match them with requirements of requesters. Finally, the fourth stake holder is a main registry that collects descriptions about the type of advertisements collected by the registries. There are three operations in ESOA, advertisement, discovery loop and interaction that carry out the protocol inquiry [7]. In the advertisement phase, each registry transfers to the Main registry information about the type of services that it has. Upon receiving the advertisement of the new service, a registry, such as registry ORG_1 as shown in Figure 2.6, updates its registration with the Main registry to show that new advertisements are available. An application at the requester, query its local registry for a specific type of service. If the registry has information about the provider of the service, it sends a report to the requester with all the details. Otherwise, it contacts the main registry to discover what other registries may know about the type of services that the application needs. It reports back on the registries that are likely to discover the needed service. In the example, the main registry reports ORG_1. At this point registry ORG_2 sends a query that it originally received from the application to registry ORG_1. The registry ORG_1 then performs the discovery process and then sends back a report to registry ORG_2 with all the information about the providers that satisfies the requirement of the application. The application then selects the best provider and starts interaction directly with the provider.

The ESOA has a number of advantages. Firstly, it allows SOA to span across organizational boundaries supporting discovery of services within other organizations without having multiple copies of registrations. Secondly, it requires very limited infrastructure. The only requirement is the additional Main registry. Finally, by avoiding the copying of advertisements it reduces the redundancy between the registries, and it does not require any overhead when the virtual organization is dismantled.

2.4. Universal Description Discovery and Integration (UDDI)

Universal Description Discovery and Integration is the standard SOA registry, because it is a standard at the OASIS standardization body and also because major companies in software Industry like IBM, Microsoft, Oracle, etc., have invested in the development of UDDI and participate in the work of the UDDI technical committee [7]. UDDI supports SOA by providing a publish API that is used by the provider to advertise the web services, and an inquiry API that allows requesters to search for web services and to retrieve information about the registered services. Web services are described in UDDI by a set of data structures that are used to specify the business that deployed the service, the service itself and all the bindings of the service.

The success of ESOA hinges on the ability to provide an effective discovery mechanism. The problem of service discovery arises as the provider and requester of the service may have different perspectives on the same service advertised. For example, a provider of the service may report many different types of information about a service, whereas the requester might need only one type of information. Thus a matching process needs to recognize the similarity between the meaning of the request and the meaning of the advertisement. The web services technologies, SOAP, WSDL, and UDDI rely on XML for interoperability.

CHAPTER III

PROPOSED APPROACH

This thesis proposes an architectural model to provide IT infrastructure for virtual organizations, so that information can flow easily within virtual organizations. The creation of virtual organizations becomes important as the services offered by one organization should become accessible to other organizations. This proposed model, that we call Virtual Service-Oriented Architecture or VSOA in short, is based on the observation that UDDI registries are themselves web services and is also a way to extend ESOA to deal with virtual organizations. In ESOA, if a situation arises where the same kind of request is placed from different customers within an organization at different times, the entire discovery and interaction phases needs to be repeated. In other words, the central Main registry is first contacted. The Main registry returns the registries that are likely to discover the set of providers which offer the requested service. The local UDDI registry which placed the original request contacts all the registries of the providers (local registries of all partner organizations). They provide more details about the providers such as the type of services they offer, the protocols they use, and other such details. The application then selects one of these providers based on some criteria. Furthermore, since there is no local caching, a customer who has previously requested a service will have to go through the whole process again if another request is made for the same service again.

Repeating the whole process is time consuming and increases the number of requests to query the Main registry as well as the requests to local registries when there are repeated requests. The proposed architecture makes the Information discovery process across organizations more flexible and efficient.

The drawbacks of the ESOA which are dealt by VSOA are, firstly, VSOA deals with the central point of failure problem. If for any reason the central point in ESOA, i.e., the Main Registry fails, then the situation reverts back to the basic SOA model where the service providers not only advertises with the local UDDI but also with all the UDDIs available in the network. VSOA deals with this problem by introducing another local registry called the Cache Registry, where all the results received by the requestor application about the services it needs are stored and are available for retrieval whenever the same kind of request is placed next time without actually going through the entire procedure again. This to some extent, if not fully, solves the center point of failure problem. Even if the Main Registry goes down, the proposed VSOA model helps to process the requests that require the same type of services that were handled before. Some simulations will be run at later stages of the thesis to get the measurements of what percentage of services can be processed even when the Main registry fails. We assume that the central point will be restored after sometime.

Secondly, suppose that the same service is requested more than once by different requesters within the same organization at different times. According to ESOA, the discovery phase has to be repeated each time the request is placed. This consumes much time and increases the number of requests made to query the main registry. In VSOA, all the information about a service requested is stored in the cache registry. The cache registry consists of information such as the name of the web service, the business that deployed the service and exact location of the service provider. Whenever the same kind of request is repeated, it can be accessed locally easily and the information about the provider of service can be directly obtained. This reduces the number of procedures it has to go through and can contact the provider directly using the provider address in cache.

Thirdly, our proposed approach reduced the communication bottleneck introduced by a central point of communications. Network traffic is much more distributed.

3.1. VSOA: Virtual Service Oriented Architecture

To support the needs of virtual organizations and to make them perform efficiently, ESOA should be extended, without requiring an organization's UDDI registries to perform the same set of operations again and again. One way to approach this problem is to think of the UDDI registry as a web service itself. Another local registry is used that acts as a registry to support discovery of service providers belonging to different organizations and contain the information about the services offered.

VSOA has five stakeholders: service requestors, service providers, the third stakeholder is a set of registries that store the advertisements of local providers to match them with the requirements of service requesters which may or may not be local, the fourth stakeholder is the Main Registry, that holds the descriptions of the type of services or advertisements collected by each of the organizations registries as in ESOA. Finally, the fifth stakeholder is the Cache Registry, which collects the results obtained by the service requester in its new service request. This registry can be viewed for information retrieval when the same kind of request is placed the next time.

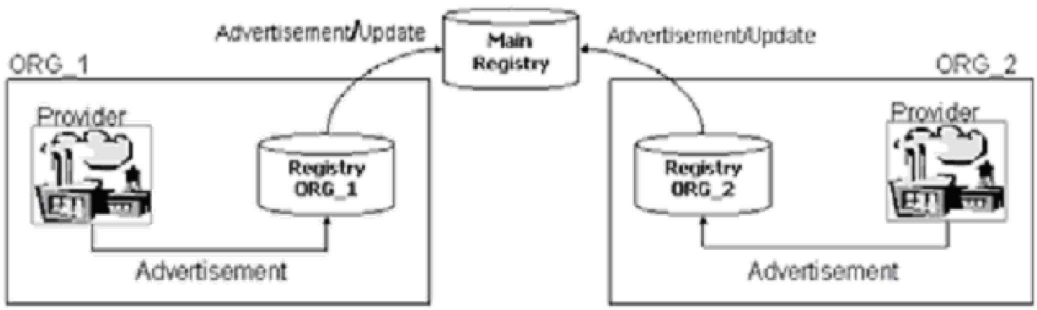


Figure 3.1: Advertising in the VSOA architecture

The four operations that characterize the VSOA protocol are advertisement, discovery, collection and interaction, which are applied to organizational registries and the services. In the advertisement phase as shown in Figure 3.1 whenever a new service is added or any changes are made to the existing services, the provider updates the local registry which in turn updates the main registry with the information and details of the services. The discovery process happens in three stages by using the local UDDI registries, Main registry and the Cache; the attributes of these are shown in Table 3.1. First, the application which needs a particular type of service queries the local organization's UDDI registry for the required information. This is because the local UDDI may contain services that have not been accessed before (new services for instance). The registries query themselves to find the information about the provider of the service. If it finds the best providers that offer the type of service requested, it reports back to the requested application. In the second stage, if the requested service is not available in the local UDDI registries, the Cache Registry is queried to check if it already has the required information about the type of service it is looking for. The cache registry holds the information of non-local services that have been accessed. If the cache search is also a miss, the main registry is queried to find the set of registries that are likely to satisfy the service that fits the request. In the third stage, the original request for services is sent to the discovered registries, which gives the details about the service provider and reports their results to the requested registry/organization. In the collection phase, the requester stores all the results it got from different registries in the Cache Registry for future referral. This approach uses the cache registry as a back up for easy and faster discovery process. Moreover, when the Main registry goes down, this Cache registry helps to serve all requests that have an entry for a corresponding provider in the cache registry. Simulations have been performed as part of this thesis to obtain a measurement of what percentage of the requests placed can be processed with the information available at the Cache registry and the corresponding improvement in performance.

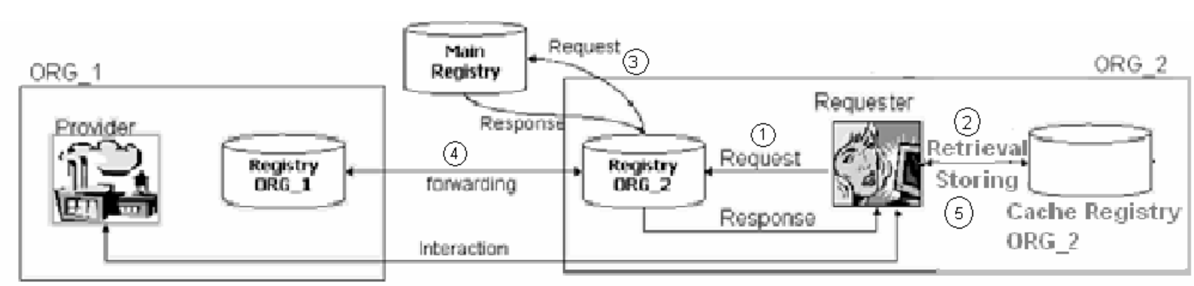


Figure 3.2: VSOA architecture protocol

Attributes	Local UDDI registries	Main Registry	Cache Registry
Name/Type of Service	Y	Y	Y
Deployed organization/UDDI	N	Y	Y
Bindings of Services like protocols, message formats, etc.,	Y	Y	Y
Location of Service (interface or URL)	Y	N	Y

Table 3.1. Attributes of different registries in VSOA

In the request phase, the application at first queries their local registry for the service type. If the registry knows about the services that satisfy the requirements of the application, it will report on those services. If service provider information is not found, the Cache registry is checked to see if it can get the required information about the type of services it is needs. The time to go through the discover process all over again will be saved if the required information is available in the cache registry. Otherwise, as shown in Figure 3.2 the local registry queries the Main Registry to discover what other registries know about the type of services that the application needs. The main registry performs the discovery process and sends back all the information about the registries that can process the request placed. In the example in the Figure 3.2, the main registry may report ORG_1. At this point Registry ORG_2 sends the original query that it received from the application directly to Registry ORG_1 which performs the discovery process, locates the best set of services and reports them back to the Registry ORG_2. In turn, registry ORG_2 reports these services, and all the other services that it discovered to the application. The application then stores these reports in the cache and contacts the provider directly.

The use of VSOA has a number of advantages. It allows the SOA to span across organizational boundaries and also saves time in the discovery process by using a Cache Registry to store the information about the type of services it already processed. The second advantage is it requires limited additional infrastructure when compared to ESOA. The only requirement is the additional Cache Registry. The third advantage is that it partially solves the central point failure problem. When the Main registry fails, the application can still be processed if a request is placed for the same type of services that have already been processed. It also reduces the traffic bottleneck at the main registry.

3.2. Response Times

We provide a simple comparison of the ESOA and VSOA systems in terms of response times.

Assume there are W web services and these are distributed across E ESBs

Assume there are C clients

Therefore on average each ESB will have W/E web services and C/E clients

Let p_{ik} denote the probability of a client requestor i at a ESB site accessing a web service k at a remote ESB site. The cost to access this is t_r

Let p_{ij} denote the probability of a client requestor i at a ESB site accessing a web service at a local ESB site i. The time to access this is t_l

The total cost for all accesses will therefore be

$$E\left(\sum_{i=1}^{C/E}\sum_{j=1}^{W/E} p_{ij}t_l\right)+E\left(\sum_{i=1}^{C/E}\sum_{k=1}^{W(E-1)/E} p_{ik}t_r\right) \qquad \text{where } t_r > t_l$$

This is the cost for a ESOA access. We have assumed that t_r and t_l are the same for all ESB sites.

The cost for a VSOA access will be

$$E\left(\sum_{i=1}^{C/E}\sum_{j=1}^{W/E} p_{ij}t_l\right)+E\left(\sum_{i=1}^{C/E}\sum_{k=1}^{W(E-1)/E} p_{ik}c_r\right)$$

Here we have defined the remote cost access in terms of a cost c_r

The cost for a VSOA access is reduced since some of the remote accesses become local accesses. Let $p_{ik}^{L\text{-}H}$ be the local cache hit probability and $p_{ik}^{R\text{-}U}$ be the remote UDDI hit probability for all web services p_{ik} that denote the probability of a client requestor i at a ESB site accessing a web service k at a remote ESB site.. As a result of caching the requested web service is available either locally or remotely.

$$c_r = (t_{l'} \times p_{ik}^{L-H}) + (t_r \times p_{ik}^{R-U})$$

where $t_{l'}$ is the time for local cache access and is very close to t_l.

It is evident that $p_{ik}^{R\text{-}U} = 1 - p_{ik}^{L\text{-}H}$

The objective is to minimize c_r. This requires identifying appropriate measures to minimize $p_{ik}^{R\text{-}U}$ and maximize $p_{ik}^{L\text{-}H}$. This simple model needs to be extended to obtain more detailed expressions for $p_{ik}^{R\text{-}U}$ atd $p_{ik}^{L\text{-}H}$. This clearly is a function of the placement and replacement strategies that will be employed. The next question that arises is which web service entries to keep in the local cache. The probability of a web service being buffered locally depends on whether the service is considered important enough to be put in the local cache. If this web service is likely to be regularly accessed, it is worth buffering it locally. On the other hand, if it is going to be accessed very rarely, it may not be worth maintaining it locally and instead to use the space for other more important web services. Therefore the characteristics of the other services that have been requested must also be considered if they should instead be placed in the local cache. A number of approaches such as least recently used or most frequently used or a combination of the different schemes may be used.

CHAPTER IV

SIMULATION MODEL

4.1. Simulation Implementation Details

The aim is to develop a simulation model for web service information discovery using both Extended Service-Oriented Architecture and Virtual Service-Oriented Architecture. Two different algorithms are developed, one to represent the working of ESOA model shown in Figure 2.6, and the other to represent the working of VSOA model shown in Figure 3.2. The simulations are limited to two organizations. The web service requesting organization is considered as the Local System and the other as Remote System. Different web service providers are available at both the systems. Since there are only 2 systems the centralized main registry is also implemented in the Remote System. Although in a real scenario, requests can be placed using different protocols, here it is limited to only the HTTP requests.

ESOA and VSOA simulation models have many components involved each performing different operations starting from placing a request until getting the results in terms of roundtrip times. Figure 4.1 shows the components and their implementation details.

Before actually writing the code and executing the working of these two models all the preliminary tasks like web services creation, creating DB2 tables, setting up of ODBC connections, etc., are to be developed initially for step by step processing of the message flow. The basic infrastructure required to run the simulations have been developed.

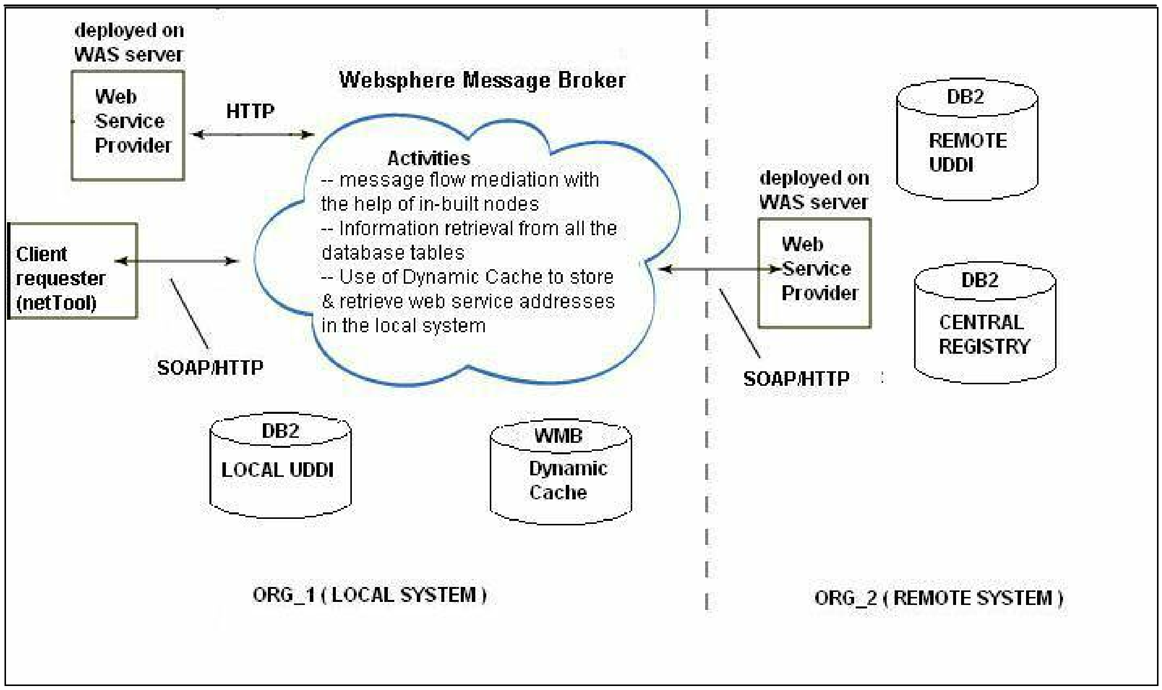


Figure 4.1: Different components and its implementation

The tasks performed before actual implementation the Algorithms:

1. **Developing simple web services in each system:** Two web services named 'Addition' and 'Multiply' are developed which takes two integers as input and gives the result back. IBM Rational Application Developer (RAD) V6.0 software is used to develop web services and web services J2EE client in the Remote System. A trial version of RAD is downloaded on the Remote System for this

purpose [11]. RAD is an eclipse based application developer used to design, develop, analyze, test and deploy web, SOA, java, and J2EE applications [10]. The web service needs a server to deploy the code generated. Hence Websphere Application Server (WAS) V6.0 trial version is downloaded [14]. Here, WAS was just used as a server to deploy the web services created. In the Local System, web service is developed using the java tool in Websphere Message Broker and deployed on WAS. The request for web service is placed using the netTool which requires the Simple Object Access Protocol (SOAP) format to post the request. The input message consists of mainly 2 parameters: the service type which is the name of the service required, and the input values. The web services available are to be published in their respective local UDDI registries in order to get recognized and invoked.

2. **Setting up UDDI registries and the communication between two DB2 databases:** In general, web services are described in UDDI by a set of data structures that are used to specify the business that deployed the service, the service itself and all the bindings of the service. It provides 2 APIs for publish and inquiry operations about web services. In this simulation, UDDI registries are assumed to be the database tables. A trial version of IBM DB2 is downloaded to setup the databases [13]. The UDDIs in the Local and Remote Systems are named as LOCAL_UDDI and REMOTE_UDDI respectively. Both these tables have 3 attributes to describe a web service, the index, service name/type, and the address of the web service provider. After the creation of web services its details are

entered into the local database tables. When a request is placed the database is queried using simple select statements based on service type.

Another table named CENTRAL_REGISTRY is created to represent the Main Registry, which collects descriptions about the type of advertisements collected by all the local registries in the virtual organization. The attributes of this table are: the index, service type, the UDDI registry where the service is available, and the datasource name which is the name of the database. The applications need to access the databases of both Local and Remote Systems to retrieve the web service address during execution. Hence, ODBC connections are setup for the databases in both the systems.

3. **NetTool Client download:** NetTool is a developer tool for monitoring and manipulating application-level network messages, particularly useful for debugging web applications and web services. It is a free access software available online. There are two components to NetTool: the HTTP Client, and the TCP Tunnel. The HTTP client is used to place a request for the web service. The request is placed as a SOAP message to the HTTP Input node of the message broker. The HTTP Input node listens at, http://localhost:7080/Algorithm2 for the ESOA algorithm and at http://localhost:7080/Algorithm1 for the VSOA algorithm. The HTTP listener at port 7080 listens to the incoming request and forwards it to the message flow of the message broker for further processing and sends back the result to the netTool. The netTool gets the value of the result for

the requested operation (Addition/Multiply) and also the roundtrip time taken to process the placed request in ms.

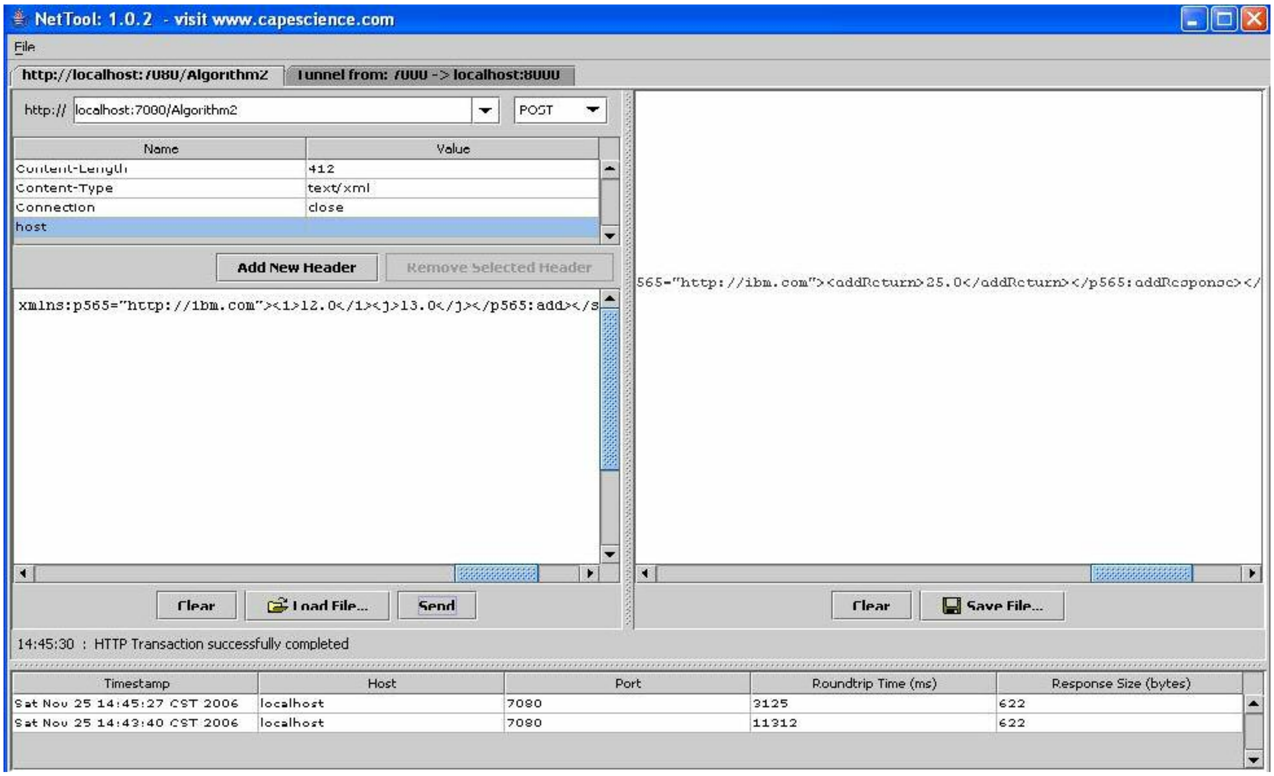


Figure 4.2: netTool Interface

4. **Websphere Message Broker (WMB) and message flows:** The trial version of Websphere Message Broker (WMB) V6.0 is downloaded in one of the systems from where the request is placed. WMB is an Eclipse-based tool that delivers an advanced Enterprise Service Bus providing connectivity and data transformation for applications and services in a SOA. It integrates with multiple sources of data such as databases, applications and files to perform data manipulation. It simplifies the integration of existing applications with web services by transforming and routing SOAP messages. The message flows are developed

using WMB which are used to orchestrate the sequences of service interactions. The role of Message flows is to define and execute processes, whose flows are determined by logic of the algorithm. The built-in nodes in WMB like HTTP Input node, HTTP request node and HTTP reply node along with the Compute node are used in the message flow implementation of the simulation models. The HTTP Input node takes the request placed by the netTool from the HTTP listener port. It then forwards the message to the Compute node where the web service address is found by querying different database tables representing UDDI registries depending on the implementation algorithms of ESOA and VSOA models. There are two different message flows for the two algorithms with all the 4 nodes mentioned above. The only difference between the two flows will be in the implementation of the Compute node. The code to perform the required operations in Compute node is written in esql language. Simple SELECT statements are written in esql to query the database tables for the information about web services offered. The web service address is dynamically computed in the Compute node and then sent to the HTTP request node, which places the request to the service provider for the required operation. A default URL http://localhost:9080/FAILURE is set at the HTTP request incase if it is not able to find the address of the service provider dynamically. The result of the web service requested is sent to the HTTP Reply node which in turn sends the result to back to the netTool.

The main difference between the implementation of the ESOA and VSOA algorithms lies in the set of operations carried out in the compute node of message broker. The message broker is a very helpful tool with its in-built functionalities such as Dynamic Cache and HTTP nodes used for data transformation and mediations. The dynamic cache provided is used for the simulation purposes. It resets itself to NULL whenever the message broker is restarted.

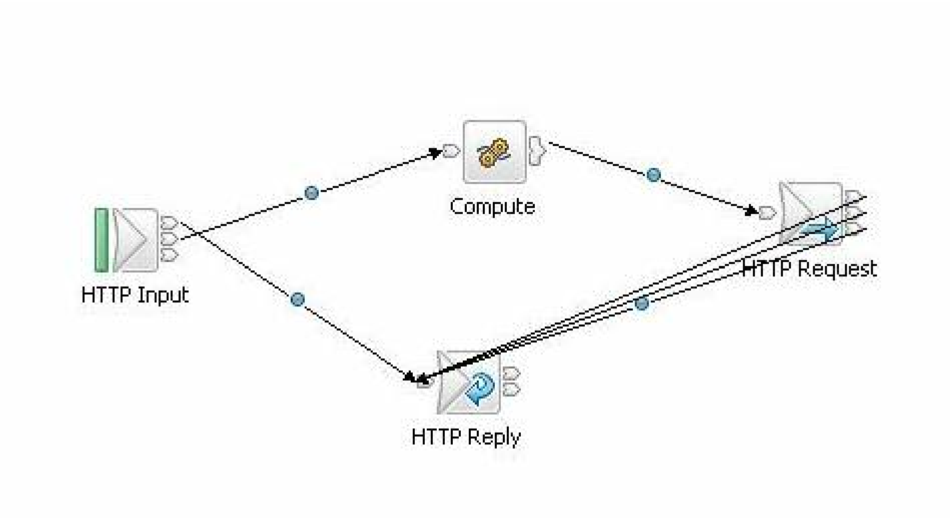


Figure 4.3: Message Flow in Websphere Message Broker

ESOA implementation: Firstly the local registry is checked when a request for web service is placed. If no service provider is found locally, the Main registry is contacted to get the information about which organization has the service providers for the requested service. The request finally goes to the remote UDDI registry to get the address of the service provider. In ESOA model, the centralized main registry is contacted every time a request is placed for the web service in remote system.

Algorithm:

```
// Request is placed to the HTTP Input node from netTool.
Given Inputs: service_type & two numbers to http://localhost:7080/Algorithm2
// Message is forwarded to the Compute node where the
// Checks the local database for web service address
{
service_address = SELECT service_address from (LOCAL_UDDI) for given
service_type;
else
        // check the central registry for the remote database address where the service
        //provider can be found
        UDDI_details = SELECT datasource, UDDI from (CENTRAL_REGISTRY) for
        given service_type;
        // Then contact the remote UDDI for the web service address
        service_address = SELECT service_address from UDDI_details registry for given
        service_type;
}
```

-- The service address is sent to the HTTP Request node dynamically which sends the original request to the web service provider at the service_address

-- The value of the result is sent to the HTTP Reply node which in turn displays it in the netTool

-- The total roundtrip time starting from placing a request to the display of result is measured by netTool in millisecond (ms).

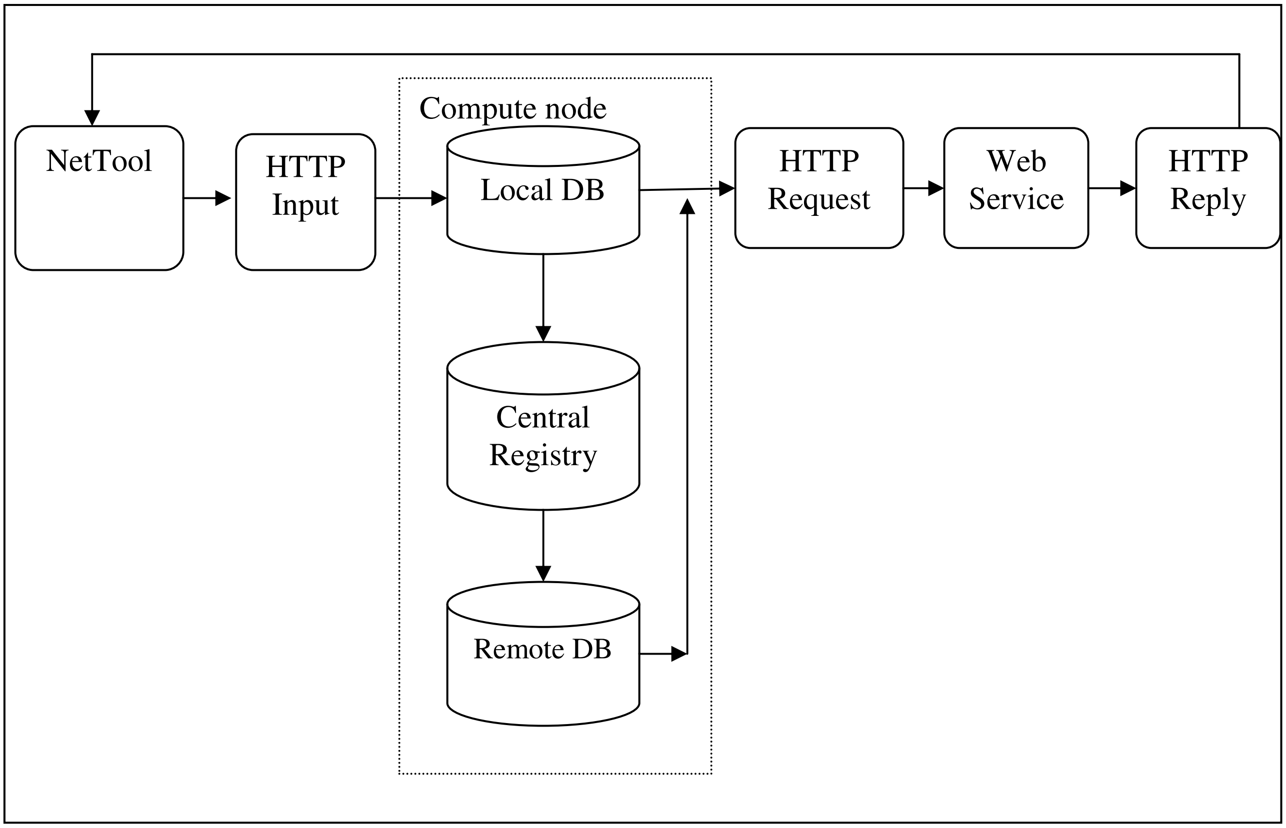


Figure 4.4: request flow in ESOA of Message Broker

VSOA implementation: A Cache is used to store the results from the remote organizations in the local organization for further referral. Here, the Dynamic Cache provided within Websphere Message Broker is used. This Cache resets itself to NULL every time the broker is restarted. When a service request is placed, the local registry is checked first. If no service provider is found locally, the Cache will be checked. Cache contains the information if the same kind of request was placed before. Else the Main registry is contacted to get the information about which organization has the service providers for the requested service. The request finally goes to the remote UDDI registry, details of which are given by main registry, to get the address of the service provider. This address is stored in the Cache for future referral. Later, when the same kind of request is placed, the service address is taken from the Cache instead of contacting the central registry again and again. In this way, the requested placed can be solved from within the local organization rather than contacting the remote organization.

<u>Algorithm</u>:

```
// Request is placed to the HTTP Input node from netTool.
Given Inputs: service_type & two numbers to http://localhost:7080/Algorithm1
// Message is forwarded to the Compute node where the
// Checks the local database for web service address
{
service_address = SELECT service_address from (LOCAL_UDDI) for given
service_type;
else
// If not found in local db, checks the Dynamic Cache using the GetFromCache method
        service_address = GetFromCache (service_type);
// If not found, check the central registry for the remote database address where the
//service provider can be found. The datasource details are taken.
        UDDI_details = SELECT datasource, UDDI from (CENTRAL_REGISTRY) for
        given service_type;
// Then contact the remote UDDI for the web service address
        service_address = SELECT service_address from UDDI_details registry for given
        service_type; }
-- Store the service_address in the Cache using StoreInCache method
-- The service address is sent to the HTTP Request node which sends the original request
to the web service provider at the service_address
-- The value of the result is sent to the HTTP Reply node which in turn displays it in the
netTool
-- The total roundtrip time starting from placing a request to the display of result is
measured by netTool in millisecond (ms).
```

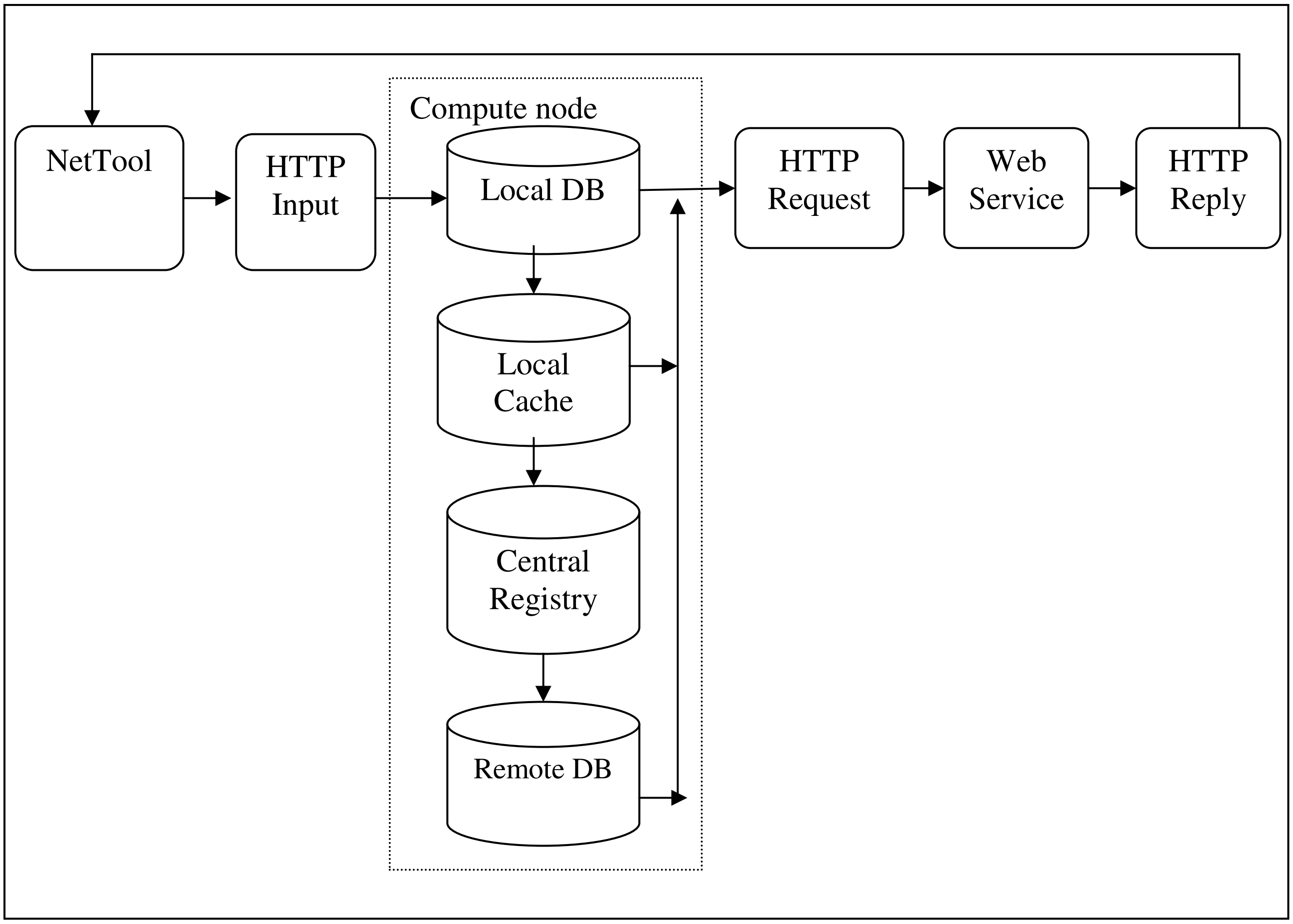


Figure 4.5: request flow in VSOA of Message Broker

4.2. Simulation Results

A total of 10 requests are placed and the roundtrip times are noted for ESOA and VSOA algorithms implemented in each scenario. Each request value shown in the graphs is the average of 10 requests placed for the same web service. The results help to analyze the behavior of both the models, their overheads, time taken to process the request placed. Standard Deviation is shown using I-form in all the graphs which represents the range within which the results of the requests placed can be obtained.

Assumptions taken while running the algorithms are:

- Even though both the systems used are in the same network, they are assumed to be in different environments while execution to depict the real-time scenario. These two systems are assumed as two organizations in the virtual organization each having its own local UDDI registries and Service Providers.
- The requests made are limited to only SOAP/HTTP protocol.
- The Websphere Message Broker is not restarted while running the algorithms, so that the Cache is also not reset to NULL.

4.2.1. Web Service Provider located in the Local Organization

If the web service provider is available in the local organization i.e., within the organization where the request is placed, the response times will be more or less the same for both the ESOA and VSOA models. The results taken when the request is placed for the web service available in the local system using both ESOA and VSOA algorithms are shown in Table 4.1. The results are taken from the netTool client. It measures the time taken to complete the request placed. The roundtrip time values vary around 200-500ms. This kind of difference may be because of some unknown network delays, speed of the system, etc. This shows that under normal conditions of operation both ESOA and VSOA functionality will be the same when the service provider is available locally.

Host	Po-rt	Resp-onse Size bytes	Roundtrip Time (ms) for the requests placed										Total Avg
			# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8	# 9	# 10	
local host	70 80	627	209	451	531	309	396	446	287	623	193	530	
local host	70 80	628	172	322	234	373	373	267	334	554	272	521	
local host	70 80	629	394	355	345	319	399	353	587	406	434	476	
local host	70 80	629	519	434	145	499	555	322	519	378	531	258	
local host	70 80	629	278	353	434	350	542	542	256	278	543	598	
local host	70 80	630	250	542	523	440	440	534	456	359	448	376	
Local host	70 80	630	456	222	250	267	406	465	406	356	299	286	
local host	70 80	630	440	187	272	534	267	272	355	498	411	357	
local host	70 80	630	359	267	240	359	272	399	190	234	523	365	
local host	70 80	630	406	446	359	272	234	187	303	334	468	404	
		avg	348.3	357.9	333.3	372.2	388.4	378.7	369.3	402.0	412.2	417.1	377.9
		Std dev	115.4	112.2	129.4	91.6	109.0	119.1	123.1	122.0	119.7	110.8	115.2

Table 4.1: Web Service located in local DB2 using ESOA & VSOA

4.2.2. Web Service Provider located in a Remote Organization

ESOA: In this case, the requested service will not be available from the local UDDI registry and have to contact the centralized main registry to get the information about the service provider. Here, the remote system is contacted twice for every request, once the central registry and again the REMOTE_UDDI. The time taken to process the request placed for 10 consecutive requests are noted in Table 4.2. The roundtrip time is measured using the netTool client. The port number in the table is the HTTP listener port where the initial request is placed. While performing the simulations the two systems are within the same network. However, in a real-time scenario these systems must be connected through the internet, hence a delay is added to the roundtrip time. This delay of 98ms is the average taken by pinging to a.cs.okstate.edu at different timings. The roundtrip times in this case are much higher when compared to the completion times taken when the service provider is available in the local system.

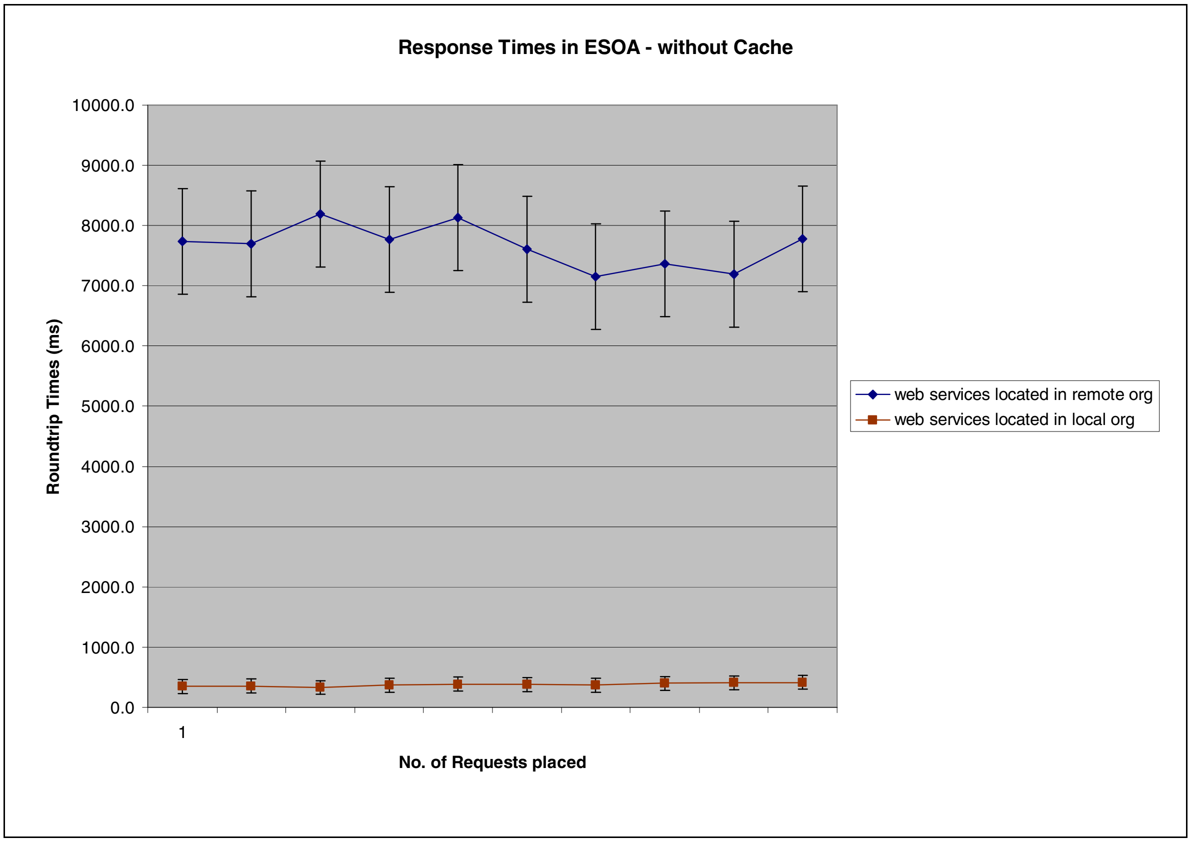


Figure 4.6: Roundtrip times vs. no. of requests placed using ESOA

A graph is plotted, Figure 4.6., with the roundtrip times vs. no. of requests placed depicting two scenarios (local and remote service providers) using ESOA model. I-shaped line representing Standard Deviation shows the range within which the values can be obtained. When the web service is contacted in remote system, a large amount of time is taken to process the request as it has to invoke the central registry and also the remote_uddi in the remote organization every time the request is placed. 10 requests are placed for the same kind of web service. The roundtrip times will be the same no matter how many times the same kind of request is placed. This increases the overheads involved when a particular web service is requested many times.

VSOA: When a web service located in remote system is requested for the first time, the central registry and the remote_uddi registries in the remote organizations are contacted. The remote system is invoked twice for this purpose. The results taken from the central registry about a web service are stored in the Cache. But whenever at a later stage, if the same kind of request for the same service is placed, the process is completed within the local organization itself using the information from Cache. Table 4.3 has the roundtrip time values for the service provider in remote organization using VSOA model.

A graph is plotted, figure 4.7., with roundtrip times of the requests placed for the web services available in local and also in remote systems when contacted using VSOA model. In this scenario for remote service provider, the same request is placed for 10 times. Hence the remote system is contacted only once according to the VSOA algorithm. For the next 9 times, the information i.e., the web service address is taken from the local Cache available. This reduces the response times and also the overheads involved in contacting the remote systems.

Host	Port	Response Size (bytes)	Delay (ms)	Total Roundtrip Time (ms) for the requests placed										Total Avg
				# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8	# 9	# 10	
localhost	7080	622	98	7395	7896	6657	8025	9907	5994	6727	7439	8442	7742	
localhost	7080	623	98	7536	9053	7496	8445	9030	6919	7184	7195	7097	7754	
localhost	7080	623	98	6442	8821	7530	6215	8751	8919	6657	7541	8410	7145	
localhost	7080	622	98	6964	7184	9354	8090	6446	7336	6932	8151	7530	8333	
localhost	7080	624	98	9262	6421	8764	7909	8209	7963	6715	8634	8690	8596	
localhost	7080	625	98	6617	7321	8410	6963	7986	7309	8554	6519	8090	7343	
localhost	7080	622	98	8238	7221	9743	7576	9641	7195	7320	7282	6062	7236	
localhost	7080	624	98	9302	8530	7901	8690	7097	7545	7354	6473	5530	8063	
localhost	7080	624	98	8473	7443	8473	6922	6062	8661	7671	6941	6085	7617	
localhost	7080	626	98	7211	7097	7617	8863	8221	8234	6443	7443	5996	7986	
			avg	7744.0	7698.7	8194.5	7769.8	8135.0	7607.5	7155.7	7361.8	7193.2	7781.5	7664.2
			stddev	1029.0	851.1	937.1	850.5	1284.6	866.9	621.2	666.5	1197.9	472.9	877.8

Table 4.2: ESOA – Web Service in remote DB2

Requests placed	Host	Port	Response Size (bytes)	Total Roundtrip Time (ms)										AVG	STDDEV
1	localhost	7080	626	8442	7211	6617	7097	8209	6932	7530	7901	6421	6223	7258.3	753.6
2	localhost	7080	622	1187	945	1054	1276	863	1238	1309	1265	1094	969	1120.0	157.8
3	localhost	7080	622	1284	876	1165	1076	945	1058	1297	978	1007	986	1067.2	141.1
4	localhost	7080	629	1188	1285	1154	1134	1007	1234	993	954	943	1010	1090.2	123.5
5	localhost	7080	625	1094	1076	1085	967	1176	1187	945	834	986	1187	1053.7	118.2
6	localhost	7080	629	969	1165	1287	1097	1122	986	1143	1262	925	1065	1102.1	120.1
7	localhost	7080	629	1000	1281	890	1054	1238	964	929	1036	1187	1198	1077.7	138.3
8	localhost	7080	626	1109	1031	963	1293	1109	1297	1198	1309	1024	1276	1160.9	130.3
9	localhost	7080	626	1281	1094	1189	974	895	912	993	1096	1123	1165	1072.2	125.8
10	localhost	7080	629	890	1298	1387	935	1053	913	945	1104	1010	914	1044.9	172.1
														1704.7	198.1

Table 4.3: VSOA – Web Service available in remote system

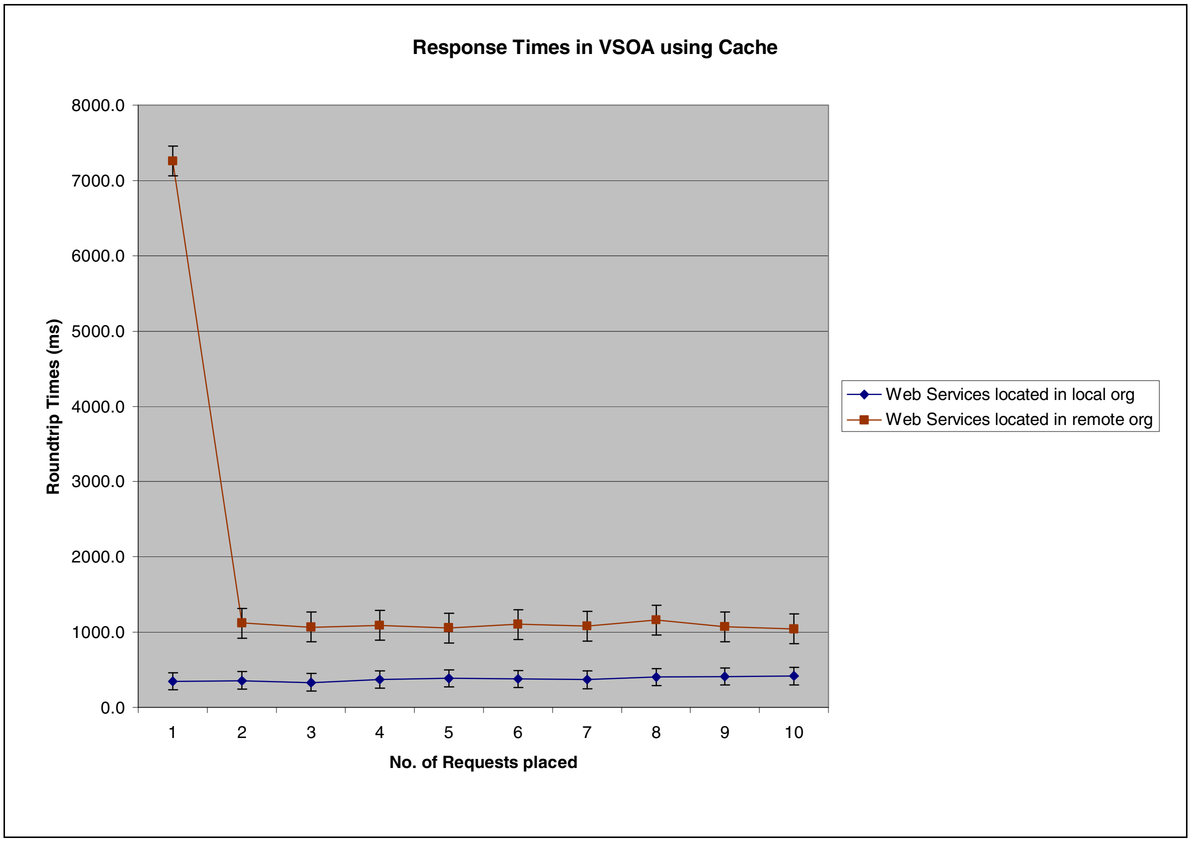


Figure 4.7: Roundtrip time vs. no. of requests placed using VSOA algorithm

Graph in Figure 4.8. Compares the roundtrip times taken to process the request of remote service provider using ESOA and VSOA algorithms. A careful analysis of the simulation results and graphs tells us that under normal conditions of operation, the proposed VSOA model will incur fewer overheads than the ESOA schema. The first time a request is placed for a web service in remote system, both ESOA and VSOA will take almost the same time to completely process the request. Starting from the second time a previously requested web service is placed, the VSOA model processes requests faster and better than the ESOA with respect to the time taken to contact the service provider in remote system using the information available within the cache.

The second issue arises when a central point of failure occurs due to any reason i.e., when the Main registry goes down. The ESOA simulation has to be stopped abruptly until the Central main registry comes up, whereas for the same scenario in the proposed model there is a chance to execute few requests depending on the information stored about web services within the local Cache. If the same kind of web service request was placed before the occurrence of the problem, then it can be processed using VSOA algorithm.

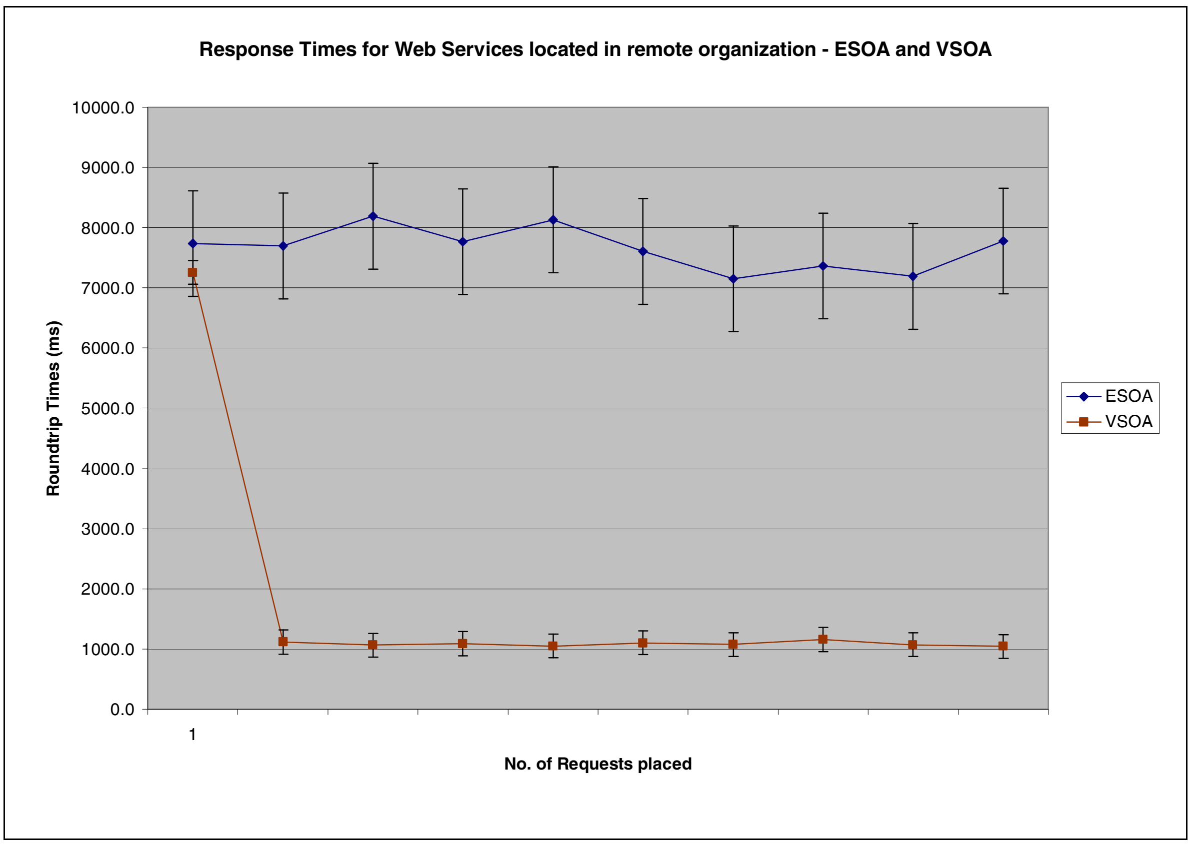


Figure 4.8: Comparison of ESOA and VSOA models

To evaluate the number of requests processed with the information available in the Dynamic Cache without having to contact the central registry in the remote system, few simulations were performed. This can help evaluate the working of VSOA under central point of failure problem. It is assumed that a total of three web services A, B, and C are available at the remote organization. VSOA algorithm is run assuming a problem has occurred with the central registry and the percentage value of the number of requests processed is noted in Table 4.4. along with the information in Cache.

Web Services available In Dynamic Cache	% requests processed using cache in VSOA
NIL	0 %
A	33.3 %
A, B	66.6 %
A, B, C	100.0 %

Table 4.4: Requests processed using cache in VSOA

The percentage value of no. of requests processed shown in table 4.4. is based on the information stored within the Dynamic Cache and also the cache reset time. It is observed that when the cache is reset or when no web service is contacted before the problem has occurred, none of the placed requests can be processed using the VSOA. If the information about one of the web service is available in Cache, then one-third of the requests can be processed. Likewise, if the information about all the web services is available with cache then all the requests can be processed. Hence, we can say that VSOA model solves the central point of failure problem partially.

In the real-world scenario of the VSOA model, if any changes are made to already available web services like an updated URL, protocol usage, etc or any new web services are added, the local UDDI registries are notified which dynamically updates the changes in the Main registry. Unlike in the simulation model, the cache size will not be reset. A limit is set to the cache size. If its maximum size is reached then replacement strategies like LRU can be used to save the information about newly accessed web services. The patterns of the graphs with the real-world results for both the models discussed will be the same as shown in simulations. There will be a wide range of results obtained as there will be multiple partner organizations each providing more than one service within a virtual organization. Furthermore, the different services will be using different protocol bindings. As the number of service providers increases, there may exists a situation where one web service will be provided by multiple providers located in different organizations. Then some other algorithms need to be developed to select the best provider available from the set of choices in the cache.

CHAPTER V

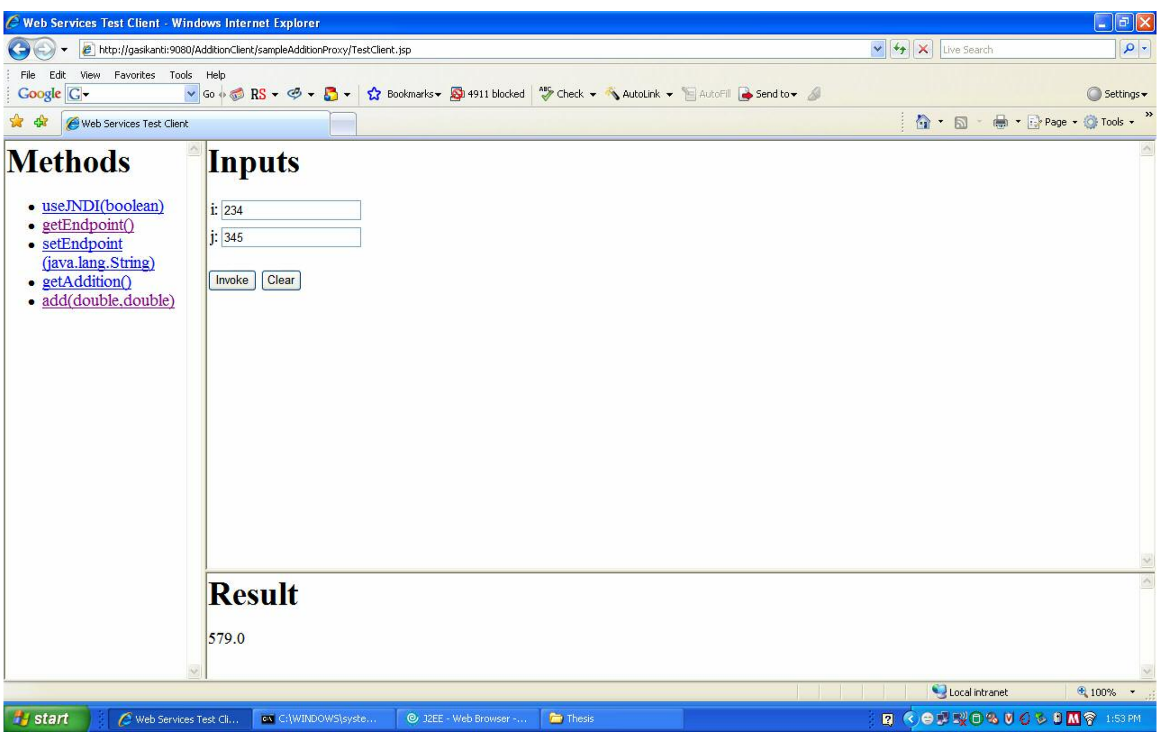
CONCLUSIONS

Four different types of simulations are run for each model discussed i.e., ESOA and VSOA. The roundtrip times to execute a request placed for a web service located in the local system are the same for both ESOA and VSOA architectures. For requests placed for a web service located in a remote system, the performance of the proposed Virtual Service-Oriented Architecture is better when compared to the Extended Service-Oriented Architecture. The performance is measured in terms of the time taken to process the request. The VSOA algorithm also supports the processing of the requests placed even when a central point of failure occurs. However, there are few limitations to our simulation. The information stored in the Cache is not updated on a regular basis. There may be chances that the web service address stored in the Cache is moved to some other URL or no longer available. In such situations, the request placed cannot be satisfied. Secondly, since the simulation depends on the communication between different environments, it is vulnerable to different types of errors and problems. There were situations where we incurred problems due to the firewalls and antivirus software.

A considerable amount of work can be done to improve the performance measures of the VSOA architecture. The amount of cache memory needed to satisfy web service requirements has not been explored. Issues such a cache replacement strategies have not been investigated. In future a real-time architecture should be developed to overcome the drawbacks of the existing systems in SOA. The problem of trust in SOA remains largely unexplored.

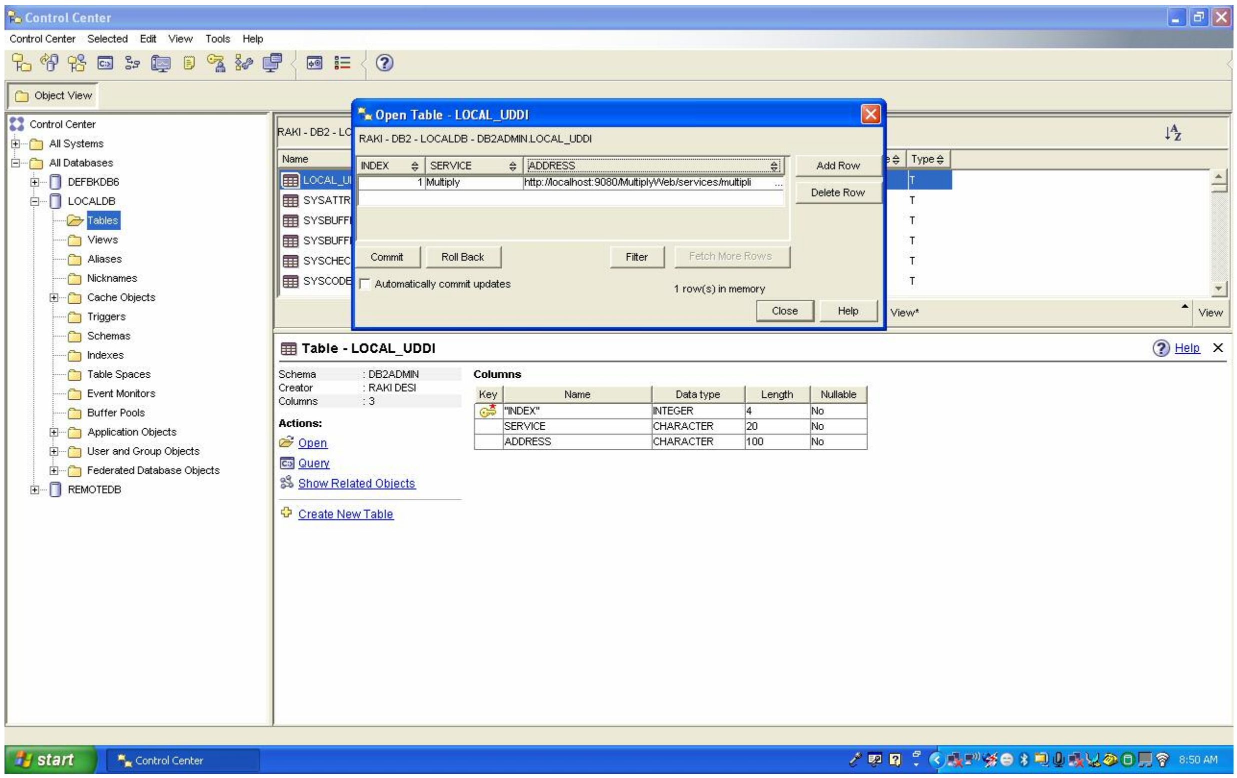
APPENDIX

I. These are the client interface (.jsp) pages of the web services created. Instead of directly giving the endpoint address of the Web Service, we are dynamically computing the web service address through the use of database tables representing UDDI registries in the simulation. This service_address is then sent to the HTTP request node dynamically and the result is taken. A netTool is used to place the request instead of this client .jsp page used to call a web service.



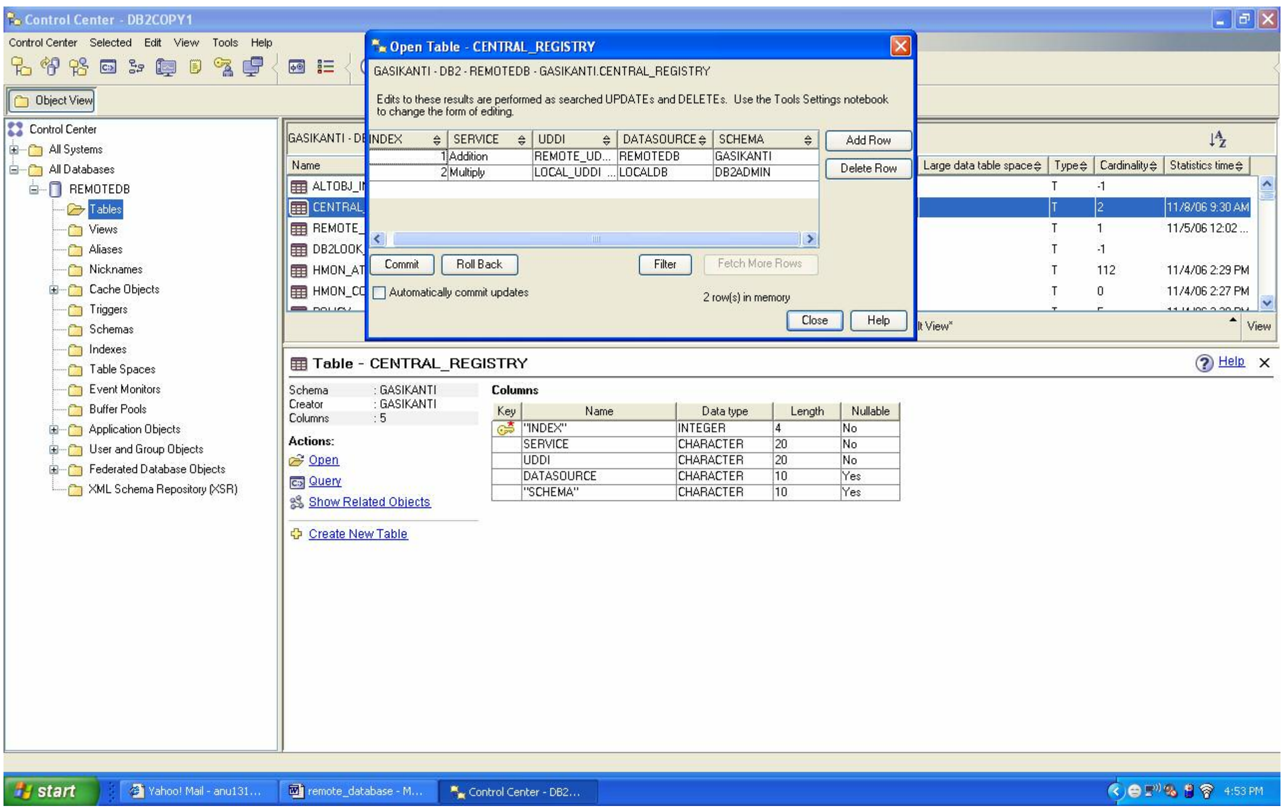
I. Web Service client page(.jsp)

II. This is the screen shot of the LOCAL_UDDI table which contains information about the Web Services offered in the Local System.



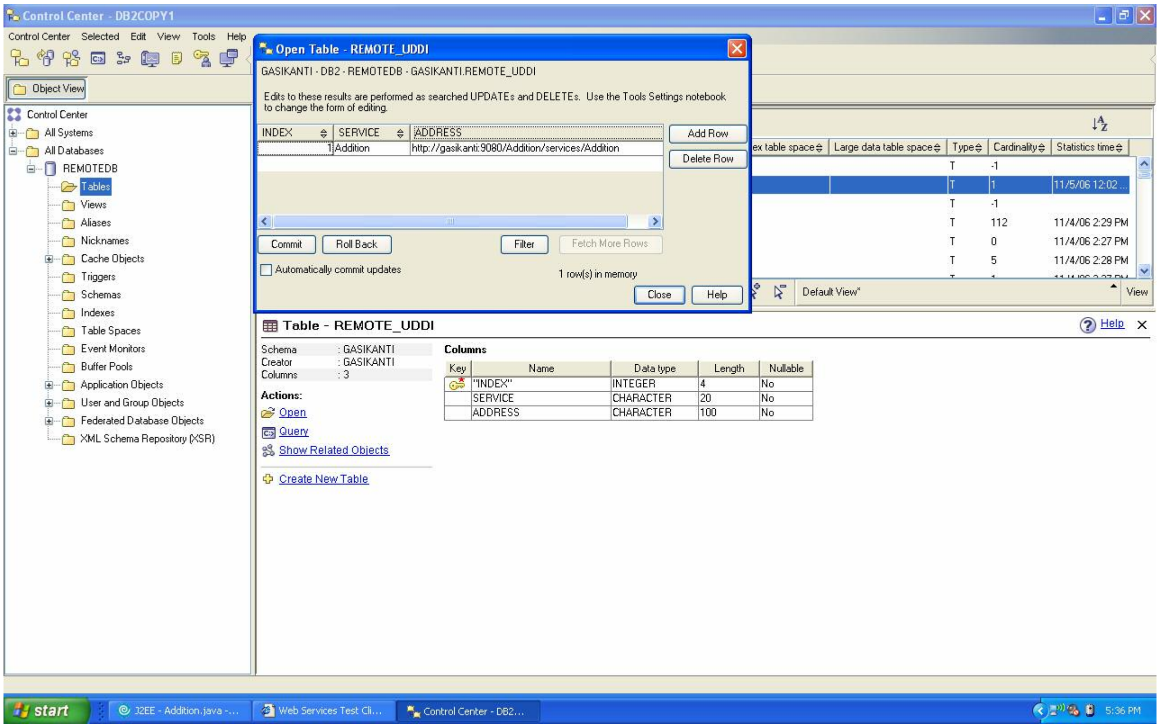
II. LOCAL_UDDI registry in the Local DB2 System

III. Screen Shot of the CENTRAL_REGISTRY located in the Remote System. This database table contains information about all the web services offered in all the systems available in the virtual organization. It has the attributes to show which web service is offered with which local UDDI registry. In this simulation only two web services are create and hence it shows information of only those two.



III. CENTRAL_REGISTRY in the Remote DB2 system

IV. This is the Screen shot of the REMOTE_UDDI in Remote DB2 System



V. The SOAP message sent to request the 'Addition' Web Service which is located in Remote System. This message is given as input using netTool. The service_type needed is given in the Header and the numbers are given in the body of the message.

<soapenv:Envelope xmlns:soapenv="http://schemas.xmlsoap.org/soap/envelope/"

xmlns:soapenc="http://schemas.xmlsoap.org/soap/encoding/"

xmlns:xsd="http://www.w3.org/2001/XMLSchema"

xmlns:xsi="http://www.w3.org/2001/XMLSchema-

instance"><soapenv:Header><Service>Addition</Service></soapenv:Header><s

oapenv:Body><p565:add
xmlns:p565="http://ibm.com"><i>12.0</i><j>13.0</j></p565:add></soapenv:Bo
dy></soapenv:Envelope>

VI. The SOAP message sent to request the ‘Multiply’ Web Service which is located in Local System. This message is given as input using the netTool. The service_type needed is given in the Header and the numbers are given in the body of the message.

<soapenv:Envelope xmlns:soapenv="http://schemas.xmlsoap.org/soap/envelope/"
xmlns:soapenc="http://schemas.xmlsoap.org/soap/encoding/"
xmlns:xsd="http://www.w3.org/2001/XMLSchema"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-
instance"><soapenv:Header><Service>Multiply</Service></soapenv:Header><s
oapenv:Body><p565:mult
xmlns:p565="http://ibm.com"><i>10.0</i><j>20.0</j></p565:mult></soapenv:B
ody></soapenv:Envelope>

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VITA

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Scope and Method of Study:

Web services are deployed within the restricted spaces of organizations intranets. There is a need for the creation of virtual organizations where the services offered by one organization should become accessible to other organizations. This requires exposing IT infrastructures to participants so that the information can flow easily within the virtual organization. This proposed model called Virtual Service-Oriented Architecture, or VSOA, is based on the observation that Universal Description, Discovery and Integration (UDDI) registries are themselves web services. VSOA is also a way to extend the existing Extended Service-Oriented Architecture model where UDDI registries are required to perform the discovery process of web services repeatedly when the similar request is placed. The proposed architecture makes the Information discovery process across organizations more flexible and efficient by introducing a Cache Registry locally within an organization. It is used to store all the results received by the requestor application about the services it needs and are available for retrieval whenever the same kind of request is placed the next time. Caching can significantly improve the response time for such applications by saving the computed results in a cache, associating the saved results with properties of the request, and serving subsequent similar requests from the cache. Introduction of Cache also reduces the communication bottleneck introduced in the previous models.

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