EMBARKING SERVICE-ORIENTED ARCHITECTURE INTO STUDENT INFORMATION SYSTEMS

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Abstrak

Sebahagian besar organisasi memiliki lebih dari satu sistem maklumat untuk pengurusan data dan aktiviti mereka. Di Universiti Utara Malaysia (UUM), Pusat Komputer memainkan peranan yang berurusan dengan pelbagai sistem maklumat berkaitan pelajar. Namun, tiada satu pun dari sistem ini berkebolehan sepenuhnya untuk merentasi atau bekerjasama (*interoperability*) dalam sistem maklumat yang pelbagai jenis *(heterogeneous)* kerana penggunaan pangkalan data dan bahasa pengaturacaraan dari jenis yang berbeza. Hal ini menimbulkan kesukaran untuk mengintegrasikan data secara automatik ke dalam pelbagai sistem maklumat. Justeru, pegawai yang bertanggungjawab pada setiap sistem perlu melakukan pemilihan data secara manual untuk mendapatkan data dari sistem lain. Akibatnya, mereka yang menguruskan sistem tersebut terpaksa melakukan kerja yang sama secara berulang kerana mereka harus memasukkan data yang sama ke dalam sistem maklumat yang berlainan. Selain itu, situasi ini juga telah meningkatkan kos operasi dan pemeliharaan sistem serta membazir ruang penyimpanan data akibat dari tindanan data yang terjadi. Walaupun di UUM terdapat satu sistem maklumat yang menggunakan satu alat integrasi untuk mengemaskini data yang diperlukan dari sistem maklumat utama pelajar, tapi ia masih tidak dapat mengemaskini data yang terkini dalam masa sebenar (*real-time*) dan ia memerlukan satu alat perantara bagi setiap dua sistem yang hendak diintegrasikan. Kajian ini bertujuan untuk mengusulkan model konseptual bagi pengintegrasian kepelbagaian sistem maklumat berasaskan konsep *Service Oriented Architecture* (SOA). Kajian kes dilakukan ke atas sistem maklumat pelajar di UUM kerana ia adalah satu sistem teragih yang besar dan agak sukar untuk dikaji keseluruhannya dengan masa dan kos yang terhad. Kaedah eksperimen prototaip dan pengesahan dari pakar digunakan untuk mengesahkan model. Hasil kajian ini diharapkan dapat menghasilkan model konseptual sistem maklumat pelajar berdasarkan konsep SOA yang sah agar dapat dijadikan garis panduan kepada organisasi berkaitan untuk menggunakan konsep SOA dalam meningkatkan pengurusan pengintegrasian sistem maklumat mereka.

Keywords: *Service Oriented Architecture*, integrasi, kepelbagaian, sistem maklumat, model konseptual.

Abstract

Most organizations have more than one information system (IS) for their data and activity management. In Universiti Utara Malaysia (UUM), the Computer Centre is responsible for various IS related to students. However, none of these systems are fully interoperable in heterogeneous IS because they are using different types of database and programming language. This causes difficulties to automatically integrate data in the heterogeneous IS. As a result, the person in charge at each IS needs to do manual selections to get data from other IS. Consequently, the same tasks will be repeated since they have to enter and re-enter similar data into different IS. In addition, this situation is increased the operation and maintenance cost, and waste the data storage space caused by the redundancy of data. Even though UUM has an IS that uses an integration tool for updating required data from the main student IS, it is still unable to update concurrent data on real-time and it needs one tool installed for each two IS to be integrated. This study aims to propose a conceptual model of the heterogeneous IS integration based on Service Oriented Architecture (SOA) concept. A case study approach was applied involving student IS in UUM because IS in a university are large, distributed and quite difficult to involve the whole IS with very limited time and cost. In validating the proposed conceptual model, this study uses experimental of prototyping and experts review. With the finding and result of this study, it is expected to produce a valid conceptual model of student IS based on SOA concept. Further, the model could serve as a guideline to related organizations in adopting SOA concept in improving the management of their IS integration.

Keywords: Service Oriented Architecture, integration, heterogeneous, information systems, conceptual model.

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We are thankful to everyone who helped and guided us through this journey in completing the research project.

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List of Abbreviations

ADX	Advance Data Exchange
ASIS	Academic and Student Information System
CORBA	Common Object Request Broker Architecture
DCOM	Distributed Component Object Model
EA	Enterprise Architecture
ebXML	Electronic Business using eXtensible Markup Language
ERP	Enterprise Resource Planning
ESB	Enterprise Service Bus
GAIS	Graduate Academic Information System
HLI	Higher Learning Institution(s)
IS	Information System(s)
IT	Information Technology
JSP	Java Script Programming
LMS	Learning Management System
LZS	Learning Zone System
PHP	Hypertext Pre-processor
QoS	Quality of Service
RPC	Remote Procedure Call
RUP	Rational Unified Process
SOA	Service Oriented Architecture
SOAP	Simple Object Access Protocol
SIS	Student Information System

UDDI	Universal Description Discovery and Integration
UUM	Universiti Utara Malaysia
SoSIS	Services oriented Student Information Systems
OS	Operating System
WSDL	Web Services Description Language
WS	Web Service
XML	eXtended Markup Language

CHAPTER ONE
INTRODUCTION

Business processes in higher learning institutions (HLI) nowadays, including those related to student matters, are supported by IT applications that are complex, composed of several disparate information systems, implemented by various technologies, and integrated with hard coupled point-to-point connections in order to meet changing demands of the business (Josuttis, 2007; Yu et al., 2011). One critical information system (IS) that supports the business processes in HLI is the student information systems (SIS) that consist of student data record, e-learning portal, examination, and graduation system. Until recently, the most common functions of SIS are to support the maintenance of personal and study information relating to handling inquiries from prospective students (Jabr & Al-omari, 2010); handling the admission process; enrolling new students and storing teaching option choices; creating class and teacher schedules; and handling records of examinations, assessments, marks and grades, and academic progression.

Information system in Universiti Utara Malaysia (UUM) deals with managing information related to students. However, none of these IS are able to fully interoperable in heterogeneous IS environment. In addition, these situations lead to an increased cost for operating and maintaining. Besides, it creates wastes data storage. As users demand for more effective and efficient system services, a study needs to be conducted to examine the possibility of redefining the current systems into a more interoperable form so that the systems can support the business processes in an integrated heterogeneous IS. Accordingly, this study tends to apply the Service Oriented Architecture (SOA) concept in planning, analysing, designing, and delivering IT functionalities of SIS as services which is more flexible and interoperable (Gabhart & Bhattacharya, 2008; Asuncion, Iacob, & Sinderen, 2010; Welke, Hirschheim, & Schwarz, 2011).

1.1 Problem Background

The capability among IS in sharing data from different IS is important in saving the data storage space in database from data redundancy, especially for large distributed

systems. This demand is seen in UUM, a big campus supported with large distributed systems with lack of interoperability features. These systems are operating in heterogeneous IS environments involving different types of databases, platforms, servers, operating systems (OS) and programming or scripting languages. For example, Learning Zone System (LZS) uses MySQL Server database, Linux Solaris OS, Apache web server and PHP programming while Academic and Student Information System (ASIS) uses Sybase database, Linux OS, Enterprise Architecture (EA) server and Java Script Programming (JSP). Since both systems are using different databases, scripting languages and servers, it is hard to integrate the data between them. Even though these IS are located in various departments, colleges, and centres, they always need to update data with other IS especially the main SIS i.e.; ASIS for undergraduate and Graduate Academic Information System (GAIS) for postgraduate that are handled by the Computer Centre of UUM. In illustrating the complexities in a bigger focus, Figure 1.1 shows a scenario for the communication in UUM consisting ASIS, GAIS, Library System, University Health System, UUM Alumni System, LZS, and College or Student Residential Hall System that are separating in the heterogeneous IS in different locations within UUM (Zainun Ngah, personal communication, May 13, 2009).

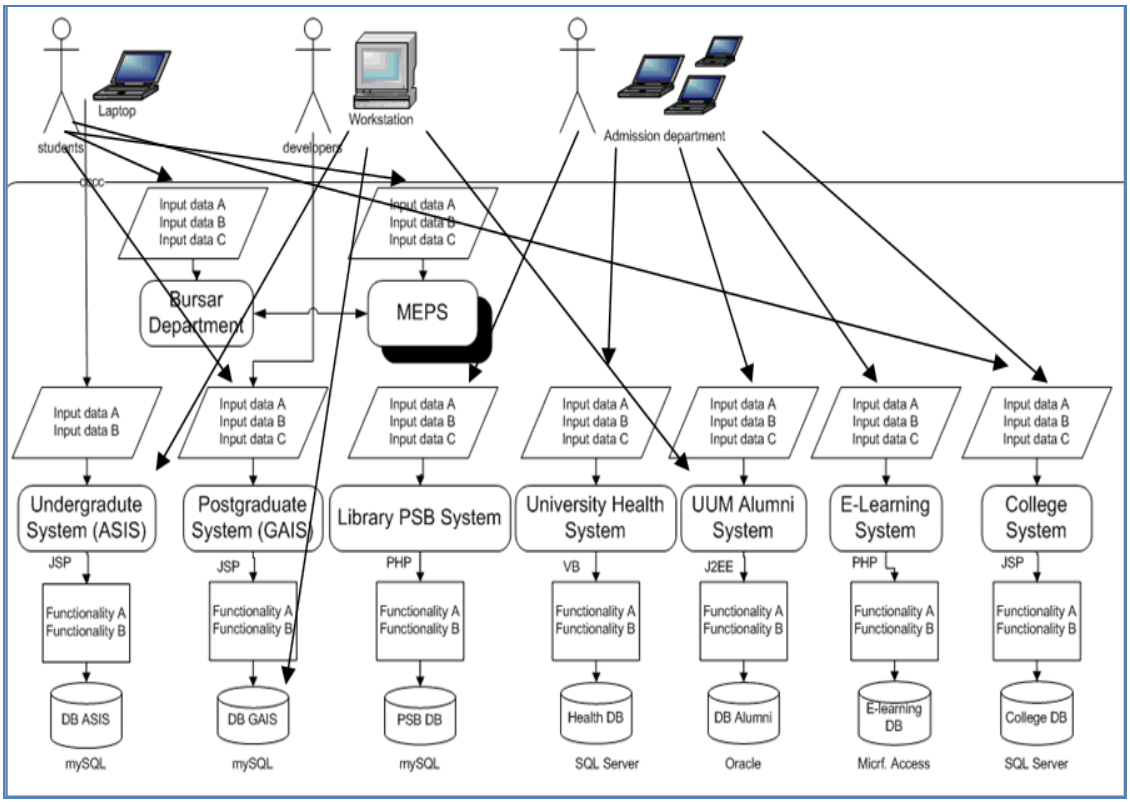

Figure 1.1: Current Scenario of the Communication Systems in UUM

The heterogeneous IS lead to integration challenges to users, especially to the persons in charge of each IS who are required to update the data. Without an automated integration, similar data has to be upgraded manually in various IS. This is a repeated task, and is a waste. This scenario can be seen in a case of a new student admission. In beginning, a student has to fill in a personal information form, in which the details are manually typed into the admission module in ASIS by the person in charge. After that, the identical process is repeated for the student residential hall or hostel. Further, some identical information is also manually typed for the library system, which uses different database and programming language. With reference to this scenario, this study argues that various IS (in this scenario are student residential hall and library) are supposed to extract certain information automatically from the main IS (in this scenario is ASIS).

However, the story is a bit different with LZS. It is a new infrastructure that makes use of Advance Data Exchange (ADX) in integrating data from a number of IS specifically ASIS, GAIS, and Personnel IS (PERSIS) (system for staff details). In short, LZS extracts information automatically without the person in charge has to type. However, the ADX is not able to fully interoperate in a large data to update all the data in the involved databases in a time. Therefore, it updates only once a day. Hence, there is cumbersome to get a data updated real time. Also, it is only applicable in LZS with several related IS since the ADX tool has to be installed in each two IS for their integrated communication.

1.2 Problem Statement

Information system that was implemented with minimum features of integrating with other IS in UUM has raised some issues. As an example it incurs additional costs for installing the ADX as in the scenario described in the previous section. Further, it also requires some maintenance cost in a long run. Furthermore, data in IS that are not connected with LZS need to be typed manually, which incurs other costs. Consequently, replicating identical data in different databases wastes the storage space since data are redundant. This explains that any changes in a system cannot be concurrently updated in the other related systems (Hidayati M.Yazid, personal communication, June 16, 2009). Consequently, requests for latest updated data on the heterogeneous IS could only be fulfilled on the next day because the synchronization process takes a long time. This is because different types of databases or programming

languages do not allow data to be practically and economically shared across the separated heterogeneous IS (Hidayati M.Yazid, personal communication, June 16, 2009).

Consequently, LZS and other IS in UUM need an alternate solution in integrating all the heterogeneous IS effectively. SOA concept was proven as a better solution for integrating among heterogeneous IS rather than another approach like (Enterprise Resource Planning) ERP system and data warehouse (Roach, Low, & D'Ambra, 2008; Hribernik, Kramer, Hans, & Thoben, 2009) since SOA could served real time data updated. In this regard, the literatures have widely described about the adoption of SOA in solving the system integration in many enterprises including in education and student IS with several conceptual models introduced by Allan (2005); Pasatcha and Sunat (2008); Lupu, Bologa, Sabau and Muntean (2008); Yen and Hsu (2008); Alkhanak and Mokhtar (2009); Jabr and Al-omari (2010); Yihui (2011); and Ying-pei and Ting-ting (2011). However, most conceptual model proposed lack of empirical validation. Thus, a study was conducted to further investigate on how to embark SOA concept into SIS in UUM for further leveraging the benefits (Kim & Yun, 2006; Mircea, 2012).

1.3 Research Questions

In addressing some solutions for the problem described in the previous section, this study needs to provide a concrete answer for "how to embark the SOA concept into SIS in UUM?" Additionally, the following questions have to be answered.

i. What are the requirements for embarking SOA into SIS?
ii. What are the technical steps involved in embarking SOA into SIS?
iii. How to prove that SOA concept can support business process and operations in SIS?

1.4 Research Objectives

The main objective of this study is to incorporate the SOA integration into SIS in solving the problems discussed in Section 1.2. In accomplishing that, the following specific objectives have to be achieved to answer the sub-questions outlined in Section 1.3.

i. To identify the requirements of embarking the SOA concept into SIS.
ii. To construct a conceptual model of SIS embarked with the SOA concept.

iii. To validate the proposed conceptual model through empirical experiments.

1.5 Research Scope

Adopting the SOA concept for integrating heterogeneous IS in a large distributed system takes a long time and is impossible to be accomplished in a limited expert team, budget, and time. To answer the research questions addressed in Section 1.3, which is specifically related to student information, a case study approach is considered appropriate and sufficient. Also since SIS involves a large distributed system in UUM, it is good to model the SOA based IS into a small sample size as a starting point. According to Roboostoff (2007), it is better to start with a small scope, to test the success of an experiment. When the pilot project has been successfully tested, then it is safe to apply in the whole systems. In this study, the main IS that are related to SIS are modelled and developed as SOA based system. They are made up of heterogeneous IS environment which are ASIS, LZS, and Library System, in which they use different types of databases and programming languages (Figure 1.2).

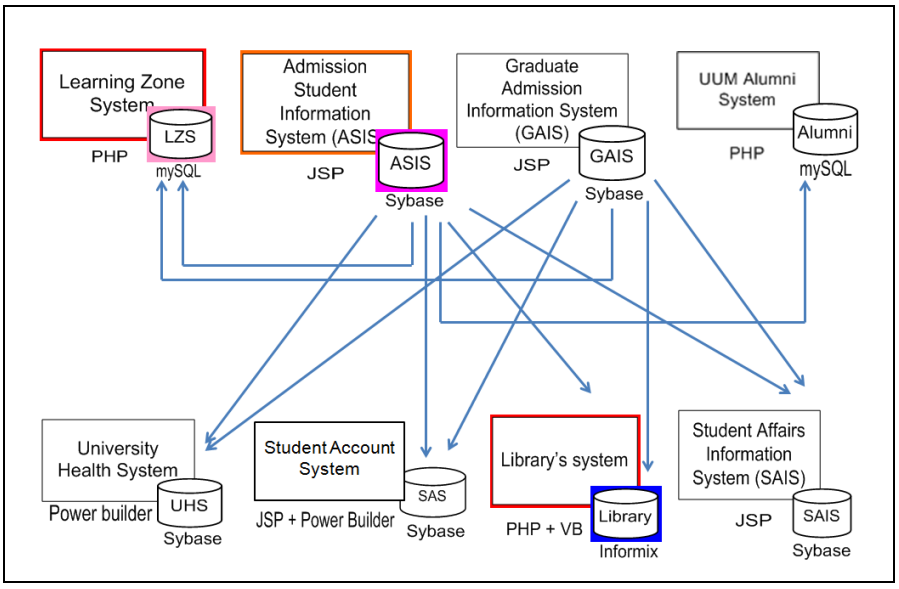

Figure 1.2: The selected IS (LZS, ASIS and Library System) of the main SIS

1.6 Research Framework

This study aims to apply the SOA concept for solving the integrated communication among different systems in a heterogeneous environment. In accomplishing this aim, various methods are involved.

As a summary, Table 1.1 exhibits the research methods with their expected outcomes and contribution.

Table 1.1: Research Framework

Title : Embarking SOA into Student Information Systems							
Research Problem (RP)	**Main Research Question (MQ)**	**Sub-Questions (SQ)**	**Main Research Objective (MRO)**	**Sub objectives (RSO)**	**Research Methods (RM)**	**The Expected Outcomes (EO)**	**The Expected Contribution (EC)**
Current SIS in UUM are not interoperable with other IS in the heterogeneous environment and causes repeating tasks in term of manual data update.	How to embark the SOA concept into SIS in UUM?	SQ1: What are the requirements for embarking SOA into SIS?	To model the SOA integration in SIS.	SO1: To identify the requirements of embarking the SOA concept into SIS.	Literature review -Document sampling analysis Interviews -SOA Experts -Stakeholders of SIS	List of SOA requirements for business process and services in relation to SIS requirements Existing architecture of SIS	A SOA based conceptual model of SIS
Meanwhile, the existing integration tool, the ADX is not able to update data in real time.		SQ2: What are the technical steps to embark SOA into SIS?		SO2: To construct a conceptual model of SIS embarked with the SOA concept.	-Consolidation conceptual models from previous studies -Consensus from experts review	A verified conceptual model of SIS based on SOA.	
Besides, the redundant data creates a big waste to the storage.		SQ3: How to prove that the SOA concept can support the business process and operations of SIS?		SO3: To validate the proposed conceptual model through empirical experiments.	Prototyping	Results of the evaluation	A validated the conceptual model for SIS

1.7 Significance of the Study

This study is important because it has explored in depth on how to embark the SOA concept into various IS in a heterogeneous environment at its conceptual level. As a result, it proposes a conceptual model for an interoperable SIS that runs with the SOA concept. Further, the proposed conceptual model has been verified by experts and empirically validated for further enhancement and deployment.

1.8 Research Contribution

By modelling the conceptual model of SIS based on SOA concept, it could help other researchers know in depth on how to embark the SOA concept for heterogeneous IS integration. Besides, it could enhance the common IS architecture or model to be highly interoperable among IS in heterogeneous environments. Further, the proposed conceptual model could also contribute to the SOA maturity in SIS domain of universities in Malaysia context.

1.9 Organization of the Report

This chapter introduces the background of the research, problem background and problem statement, research questions, research objectives, research scope, research framework, the significance and contributions of the research. Meanwhile, the remaining parts of the report are organized as follows:

Chapter 2 reviews the current SIS, literatures related to the importance of SOA and its characteristics for embarking into SIS. On top of that, it also reviews and identifies the requirements of SOA to be incorporated with SIS through the related previous works.

In Chapter 3, description of the research design is addressed. The works are divided into data collection, conceptual model development, and model validation phases. Additionally, the appropriate system development methodology is also discussed at length in development phase.

Next, Chapter 4 discusses the data analysis and its outcomes using content analysis technique. The gathered data were be used to design the conceptual model of SIS with SOA concept incorporated within.

Then, Chapter 5 follows by proposing the conceptual model, several related previous studies were compared and consolidated consistent with the SIS requirements for heterogeneous IS integration. On top of that, the prototyping experiments are also addressed. Nonetheless, the findings are also discussed. This is followed with an overall summary in Chapter 6.

1.10 Summary

As the conclusion, this chapter formulates the problem statement, research questions, research objectives, its focused scope, significance and contribution of the research. There is also a brief outline on the report organization. All the attempts in this study as outlined in Section 1.4 are supported with previous works available in the literatures that are discussed in detail in Chapter 2.

CHAPTER TWO
LITERATURE REVIEW

2.1 Overview of Literature Review

This chapter discusses the current and previous works related to this study. In supports of accomplishing the objectives, the following topics are studied. They are discussed at length in separated sub-sections below.

2.2 The Current Information Systems in Higher Learning Institutions (HLI)

Information system is very important for organizations and individuals in the world of computing for managing their data effectively and efficiently. Most organizations have more than one IS, built using different types of databases and programming languages. Further, according to this situation, it is very difficult to combine the data (Halevy, 2001).

A study by Klink, Oberweis, Ried, and Trunko (2006) found out that the existing IS in HLI were mostly developed separately in different locations with heterogeneous environments of databases and programming languages. Any data changes and to obtain the updated data, could not be done in real time because those ISs are difficult to integrate on the heterogeneous environments. In contrast, changes either from a business perspective or technical perspective is vital to deal with IS changes (Elfatatry, 2007). This is because the IS like learning management system (LMS), has to ensure any latest data or information can be retrieved by the users especially students and lecturer on time.

Similarly in UUM, SIS run in a heterogeneous environment. Out of the many IS, this study focuses only the main IS related to students, specifically ASIS and GAIS. Besides, LZS and other IS are also within secondary focus. ASIS consists of five modules, (1) admission module, (2) course registration, (3) timetable module, (4) examination and (5) graduation module. This system records all undergraduate students' information that is required by the university and its community. Similarly GAIS consists of identical modules. Both of these systems are frequently referred to by other systems such as the library system, LZS and health system for data sharing.

However, since there is no automated integration, the person in charge has to work manually with data in those IS.

Every IS in UUM has its own architecture. In detail, the logical architecture is tightly coupled among the four layers; infrastructure, domain, application and presentation layer. However, Chapter 1 states that LZS has an automated integration tool called ADX in which the architecture is depicted in Figure 2.1. There are two main ISs integrated by ADX tool; university database which is mostly used by ASIS and LZS that consists of several modules. Learning Zone System is used by students and lecturers for their learning and teaching purposes as well as students' data recording. On top of that, students also have their own portal, where they can update their personal data. Therefore, the integration is very crucial. However, ADX uses batch processing to synchronise systems at regular intervals, making data are updated only once a day. As a result, when users need real time data, the system is not able to provide ad hoc. This means the system is not fully interoperable.

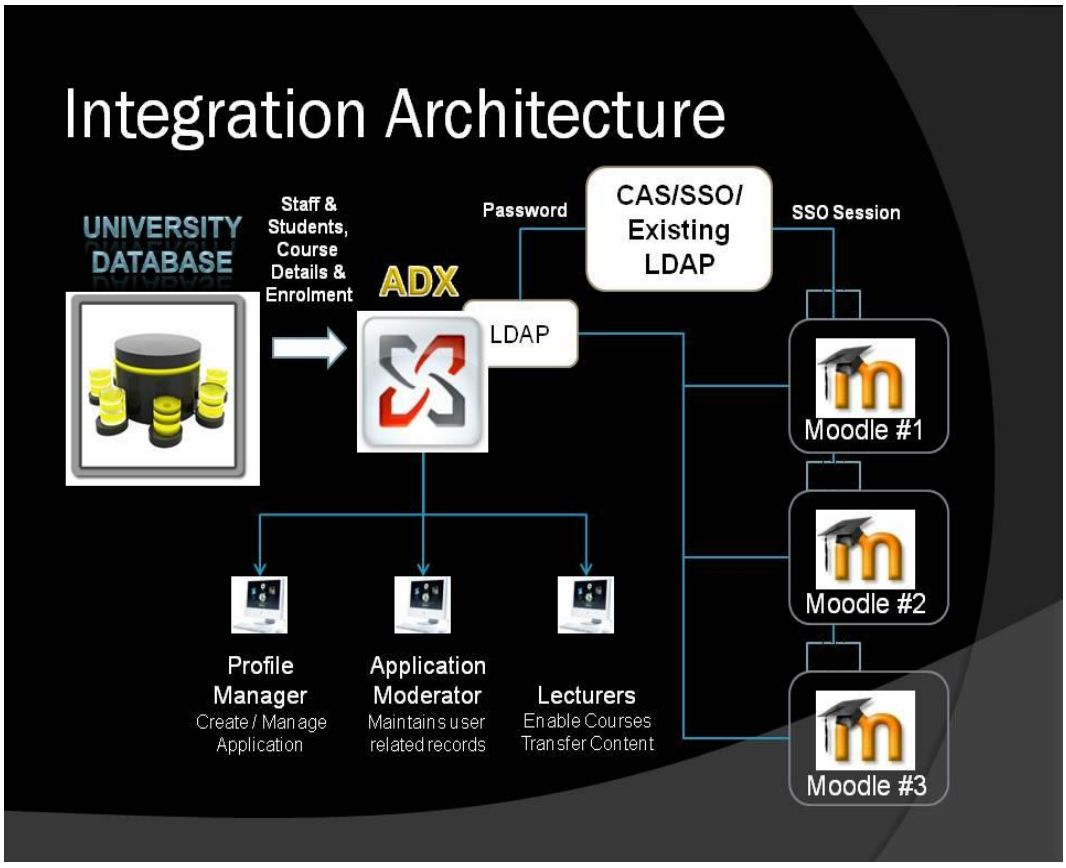

Figure 2.1: LZS Architecture

Hence, a design of IS with high interoperability is very useful for heterogeneous IS integration efficiency (Granebring, 2007). Therefore, a study to improve the current IS integration architecture of SIS need to be done. The next section further describes about SOA and how it can help to improve the legacy system of heterogeneous IS integration.

2.3 Data Integration Approaches

Different data integration approaches have different way and impact. The most popular approach is data warehouse where it is quite efficient for data integration. But there is a weakness where it still has a latency time during data updating activity, where the gathered data from another database need to place in a local database before to be updated into another database. Besides, data warehouse is categorized into tightly coupled of data integration mechanisms (Hribernik et al., 2009; Zhang & Shao, 2011; Chan, Choo, Lau, & Yeoh, 2012), which is difficult to directly integrate with different type of database. Therefore, this approach cannot be data updated on real time automatically. Compare to SOA approach that is loosely coupled, it can be on real time data updated (see Figure 2.2)

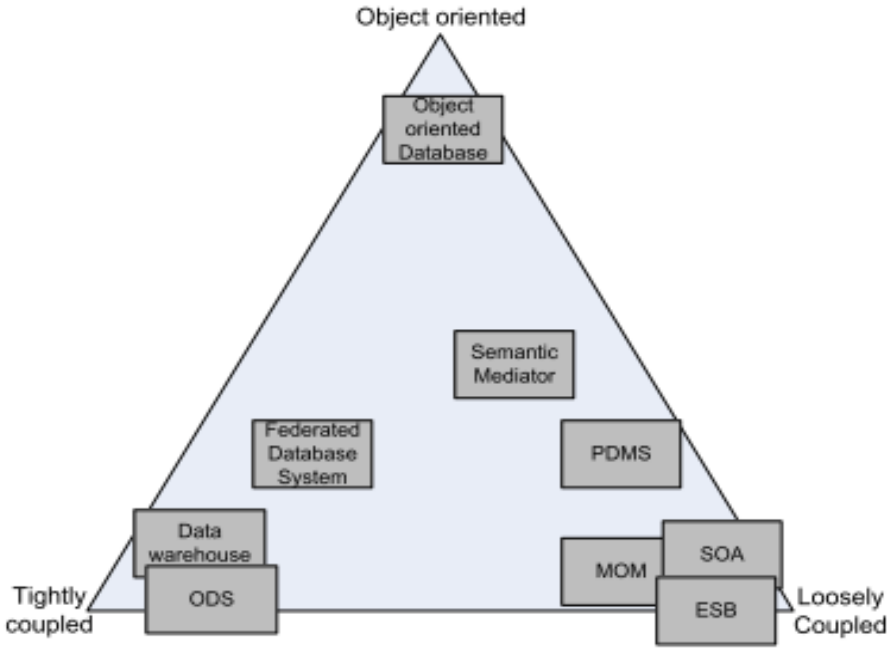

Figure 2.2: Classification of Data Integration Approach (Adopted from Hribernik et al. (2009)

2.4 Service Oriented Architecture (SOA)

SOA is an architectural style that is based on a service concept. It forms the basic SOA principles including reuse, loosely-coupled, encapsulation, interface/appearance strict definition and dynamic nature (Bo & Kaihu, 2010). Nonetheless, SOA is defined differently by different people and organizations (Gabhart & Bhattacharya, 2008). For instance, Erl (2005), Bhakti and Azween (2009) defined SOA as an approach to design architectural systems for large distributed systems. OASIS Group defines SOA as a powerful framework for matching the needs and capabilities and for combining capabilities to address those needs (OASIS, 2006).

Meanwhile, Paras, DeBoever, and Westbrock (2007) emphasize that SOA is part of the Enterprise Architecture (EA) and can be a key driver to restart the EA. At the same time, Grigoriu (2007) agreed with both that it is about architecture of an enterprise where the architecture is the structure of compound components that makes up a system through the high-level view of a structural system (Lu, Duan, Li, Zhao, & An, 2005). While in regard to this, based on the problem related to system architecture and integration, this study agrees with Bieberstein et al. (2005), OASIS (2006), and Bo and Kaihu (2010) that SOA as a framework for integrating heterogeneous data and business process based on web services concept with highly interoperable.

In SOA environment, IS operates with a collection of services. In fact the term of service in SOA means self-contain business functionalities and the bridge between the business and IT gap. In practical, services in SOA are defined in a similar way to the definition of service in the business world, which is as deeds performed by service provider for the benefits of service client. In other words, the service provider has some capabilities that are expressed as services and get invoked by the service client in order to satisfy their needs. Further, Papazoglou and Georgakopoulos (2003) state that, services are self-describing, open components that sustain rapid and low-cost composition of distributed applications, while architecture is a combination of models that describes a structure of subsystem's components, which is defined by the combination of those models. SOA has emerged into the business world as a highly prominent architectural style (Viering, Legner, & Ahlemann, 2009), in which its concepts are adopted in practice based on architectural elements and design

principles (Legner & Heutschi, 2007). On top of that, Bass, Clements and Kazman (2003) define architecture as structures of the system, which comprises of components, the externally visible properties of those components and the relationships among them. Therefore, architecture of a system could be defined as a model that describes the structure of a software system in terms of computational components, the relationships among components, and the constraints for assembling the components. In accordance, the SOA concept is further discussed in the following subsections.

2.4.1 SOA Fundamental

SOA is a system design approach for enabling interaction across heterogeneous IS. An IS developed based on SOA concept will provide a loosely coupled suited with services that can be used within multiple separated IS from several business domains. The initial idea of SOA involves four actions or paradigms to a service, which are to publish-find-bind-execute service (Michlmayr et al., 2007). Those paradigms mean applying a concept of publishing something, then another side searches the published thing, has a contract agreement, agreed to accept and be accepted. Based on that, a number of authors (Erl, 2005; Michlmayr et al., 2007; Mahmood, 2009; Aydin & Yalcinkaya, 2011) agreed that the SOA fundamental so called as SOA theory has three main elements as shown in Figure 2.3. There are service providers who provide their services to be public namely service registry or also known as a service directory. The service registry will provide service descriptions that are published by the service providers to service consumers or requestors (Mahmood, 2009).

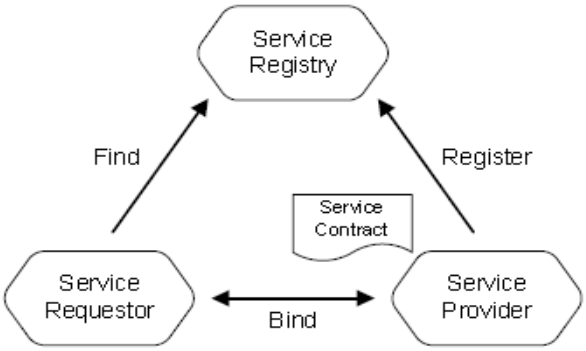

Figure 2.3: SOA Theory (Adopted from Michlmayr et al., 2007)

The commonly used standard service registry is Universal Description Discovery and Integration (UDDI), and Electronic Business using eXtensible Markup Language (ebXML) (Chiusano, 2003; Mukhi et al., 2004; OASIS, 2005). When the service consumers found the service required, service registry will inform the location of the service, where the service consumer can invoke the operations of the service and binds to service endpoint. These basic paradigms will give a loose coupling as a fundamental concept of SOA (Josuttis, 2007; Mabrouk, 2008). Therefore, it could reduce dependencies between different systems (Stal, 2006). Besides, loose coupling of SOA characteristics enables high interoperability (Josuttis, 2007) that can also make a real time data updating. This attribute is very important in solving the systems integration problem especially for the heterogeneous systems.

In practice, most IS however doing not follow the SOA triangle in Figure 2.3. Instead, only two elements are in focus; service providers and service requestors as shown in Figure 2.4. It requires the service requestors or consumers to know the right endpoint address of a service (Michlmayr et al., 2007). This contrasts the basic theory, in which it does not result in easily flexible architecture and loosely-coupled systems because service providers and service requestors are near tightly coupled. The binding between service requestor and provider is limited to a certain system that has been defined by the system provider (Leymann, Roller, & Schmidt, 2010).

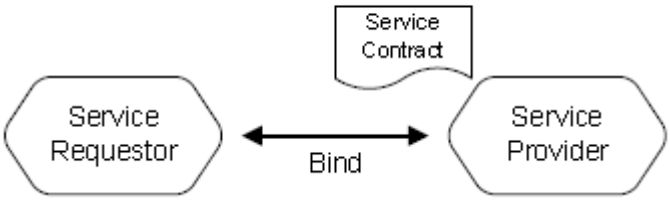

Figure 2.4: SOA Practice (Adopted from Michlmayr et al.,2007)

2.4.2 SOA Importance

The SOA theory and practice had emerged into the business world as a highly prominent architectural style (Viering et. al., 2009). By implementing the SOA concept into an application or web based IS, many benefits will be received by stakeholders and organization involved. Several factors that contribute to the

valuable benefits are influenced by the SOA characteristics especially services, loose coupling, and interoperability.

The services' characteristics give advantages to users who request for exchanging information across the network. Particularly, data exchange or update can be done easily in real time. Besides, these services are reusable, independent and can compose aggregate services by combining it with others. Therefore, it could reduce the cost on the change made to the system, or the creation of new services, and maintenance (Legner & Heutschi, 2007).

The loose coupling is course-grained services (Raghupathi & Kesh, 2007). It is very suitable for any modification and changes on the system without disturbing other components in the system since its service interface is independent on the implementation. This open standard characteristic provides interoperability, in which it can interoperate with various applications or IS. Loose coupling, on the other hand, is the best characteristic for reducing system dependencies. It will easily integrate with any type of database and programming language efficiently (Raghupathi & Kesh, 2007).

The integration of heterogeneous systems is the main issues in this study. By applying SOA concept, there is a potential to address this issue by opening up the functionality with a standardized and interoperable interface (Raghupathi & Kesh, 2007). Besides that, the SOA characteristics could also empower student and faculty by supporting a wide range of academic and business processes as well as changes the business processes, even cross departments, systems and other institutions. The traditional system in educational services are not able to support IS architectural flexibility due to their isolated IS and complicated designs but every day the demand for modularized and personalized educational services is growing. By providing IS architecture based on SOA, it can allow scalable environment. This means any modification of the system services can be made and grow easily without interrupting the core architecture, so its maintainability of the educational services is easier (Pasatcha & Sunat, 2008). This explains that the model based on SOA concept could help the educational sector develop their IS with efficient, reasonable cost, and dependable services. The advantages of SOA concept was agreed by Erl (2008) who viewed SOA as a way to be loose coupled software components or the services from

different legacy systems to empower business agility and facilitate the reusability of software assets.

The drivers for SOA adoption in this study include flexible, cost, easier development application and cross platform integration, improve software quality, implementation of changes required to meet users' requests, better reuse and software management. It relies on the usage and requirements of the system and therefore, it is advised by Yu and Ong (2009) to adopt SOA if the systems need to interact with heterogeneous IS environment. This relates with the SIS requirement that deals with various types IS environment and services. In fact, the decision to implement SOA into SIS is also supported by Muller et al. (2009), who define SOA not only as a set of design principles, but also as the best practices for the execution of automated integrated business processes in heterogeneous IT environments.

Therefore, the administration costs could consequently be reduced with better information visibility and can achieve business agility. In fact, the SOA concepts that enable sharing of data sources can also make IS development works more efficient and operating more effectively with just in time integration capabilities. Also, the SOA based model allows for simplifying integration (Alonso et al., 2003; Papazoglou & van de Heuvel, 2007). In summary, SOA makes tasks simpler, easier and reduces time to complete administrative tasks (Lindsay & Spencer, 2007). As a summary, the importances of SOA were simplified in Table 2.1.

Table 2.1: SOA Importance

SOA Importance	(Hau, Ebert, Hochstein, & Brenner, 2008)	(Lawler, Howell-barber, Colton, & Grant, 2009)	(Chen, Kazman, & Perry, 2010)
Interface orientation	☑		
Standardization	☑		
Autonomy and modularity	☑		☑
Business orientation	☑		
Organizational agility	☑	☑	☑
Less complexity	☑		
Increased reusability	☑	☑	☑
Better interoperability	☑		☑

Rapid changes		☑
Cost effectively		☑
Business process improvement	☑	
Enhanced customer service	☑	

Based on the discussions in the previous paragraphs, therefore, the SOA concept should be adopted into IS development in universities environment. It is sufficient because the SOA implementations can potentially greatly reduce the needs for changing and replicating data across the application (Roach et al., 2008). It will help reducing repeated tasks, technical issues of system integration and maintenance cost in the university management and operations. An effort to apply the concept of SOA in solving system integration issues in UUM is expected to give more benefits to the university for effectively and efficiently manage its IS as well as to provide some insights to other HLI in searching solution for heterogeneous IS integration. Previous studies that related to SOA adoption in several domains included in the HLI will be described to the next section.

2.5 SOA Adoption

SOA has been widely adopted since a few years ago in different IS sectors (Yu & Ong, 2009). Legner and Heutschi (2007) suggest three primary factors of SOA adoption. The factors of SOA adoption are the standardized integration infrastructure, for decoupling application domains and for flexible user or business process integration. All these factors have their own benefits, which relate to the cost of IS integration, the manageability of IS development and operations as well as business benefits related to a faster realization of IS support respectively.

Service-orientation aims at loosely coupled services to support the requirements of business processes and users. SOA thus appears to be a useful tool for the integration and migration of various software systems. On top of the architecture, McGovern et al. (2003), Booth et al. (2004), Baskerville et al. (2005), Klesse, Wortmann and Schelp (2005), Brown (2007), and Erl (2008) who had adopted the SOA, indicated that the main factor to adopt SOA is the SOA design principles including interface orientation and interoperability. Relating to this, as a starting point for adopting the SOA into SIS, this study applies a set of SOA importance proposed by Hau, Ebert,

Hochstein, and Brenner (2008) as listed out in the previous section of Table 2.1. Hence, its validity has been done on these aspects by them.

2.5.1 SOA Adoption in Universities Systems

The previous studies (Pasatcha & Sunat, 2008; Mok & Fong, 2008) have shown that many educational institutions have incorporated the SOA concept into IS development for integration, such as the University of Wisconsin at Madison, Embry-Riddle Aeronautical University, and Cornell University (Eduventures, 2006). They have problem-benefit relationship as outlined in Table 2.2.

Table 2.2: SOA Adoption in IS Universities

The university	**University of Wisconsin at Madison**	**Embry-Riddle Aeronautical University**	**Cornell University**
Problems to solve	To get control over its enterprise data to make sure that campus' users are work with accurate versions, getting the information needed and only official data they were authorized to deliver.	Need a robust, highly agile, and scalable ERP system that could provide its globally dispersed staff and students with real time, web-accessible services and improving the speed and accuracy of its business process.	Multiple systems allowed developing and investing in silo applications with little regard to the implications for enterprise wide integration. The existing Cornell system encompasses three major database applications, four operating systems, four hardware platforms and six development centres.
Benefits of SOA adoption	-Eliminating the "data misinterpretation" problem because all data called up from a master registry, the source of truth. -any decisions will be expedited due to the information is served up dynamically, in real time.	-Faculty and staff could accomplish key tasks faster with less difficulty. -saves cost and time in completing a process. -improved ease of use for all communities of the university.	-Business process improvement. -allows users to view enterprise data dynamically across silo applications and to access componentized applications as needed.

The three universities above had been succeeded in implementing the SOA concept into their IS environment (Eduventures, 2006). Table 2.2 states that University of Wisconsin at Madison has accomplished its aim in eliminating data redundancy, getting the information needed on real time, and improved their security for only official data they were authorized to receive. At Embry-Riddle Aeronautical University, the adoption of SOA had contributed to a robust, highly agile, and scalable ERP system that could provide its globally dispersed staff and students on real time, web-accessible services and improving the speed and accuracy of its business process. These efforts had saved sufficient cost and time in completing a process for the university. For the case of Cornell University which earlier had a problem in integrating their different IS and silo tasks, they had improved the integration process and allowed users to view enterprise data dynamically across silo applications as well as to access componentized applications as needed. Other examples of successful SOA adoption by universities can be seen at Ball State University (IBM, March 2009), City University London (JISC, October 2008) and Queensland University of Technology (Oracle, April 2008).

In Malaysia, a small number of studies have been conducted on SOA adoption with Web Services (WS) technology into IS of universities environment (Alkhanak & Mokhtar, 2009; Fang & Sing, 2009). A study was conducted by Alkhanak and Mokhtar (2009) at a university in Malaysia, where the SOA concept was applied into a postgraduate student department (PGD) system, consist several modules of applications. This is to overcome the legacy systems that are decentralized and separated. In the end, the study produced an SOA web services framework as depicted in Figure 2.5. The results show an increased level of students' satisfaction in using the systems services. However, they do not discuss in terms of how to implement the SOA concept for heterogeneous IS integration.

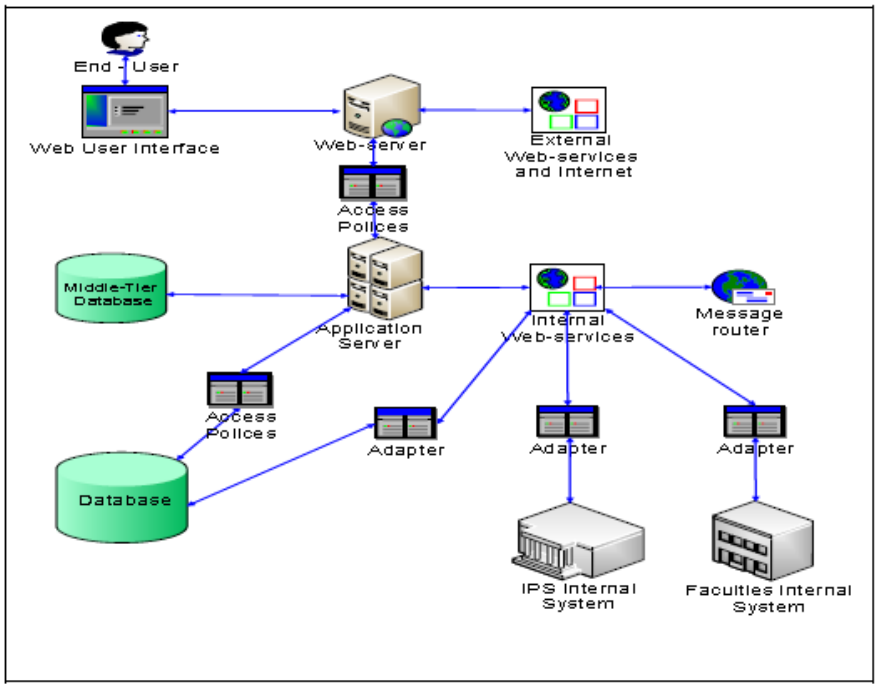

Figure 2.5: SOA web services framework adoption (Adopted from Alkhanak & Mokhtar (2009))

A research conducted by Mason and Ellis (2010) found that SOA benefits a lot in education sector, and they had proven that LMS turns into highly interoperable by implementing SOA. However, adopting a standardized SOA in the education sector is quite difficult since the legacy systems have to keep on operating as decentralized enterprises at the same time (Liu & Yang, 2008). Additionally, translating it into a scalable and real time environment is quite challenging (Selamat et al., 2009). Hence, they suggest that a detailed conceptual model of SOA based IS has need to be researched for at least integrating the heterogeneous IS with other small systems. However, the guideline for embarking SOA into SIS is still unclear since many SOA projects were unsuccessful (Granebring, 2007). Thus, a study is needed to further experiment the SOA adoption to embark its concept into SIS in UUM for further leveraging the benefits (Kim & Yun, 2006).

2.6 Standard Technologies for SOA

SOA will be more rigorous when implemented with powerful technology as a middleware or communication protocol that helps achieve the interoperability efficiently (Britton & Bye, 2004) like Web Service (WS), Remote Procedure Call

(RPC), Distributed Component Object Model (DCOM) and Common Object Request Broker Architecture (CORBA). Besides, the technologies also refer to computer systems (hardware, software, and data) and user support services (such as training, and help lines.). Web services technology has been widely used as a middleware in implementing SOA concept into IS in the education institutions to support interoperability (Selamat & Kharusi, 2009) and loosely coupled. Web services provide a loosely coupled design (Roach et al., 2008), in which it is absolutely platform and language self-governing (Abrams & Andrews, 2005). It could be utilized in developing systems (Garikipati & Lim, 2006; Roach et al., 2008) suited with services that can be used within separated IS from several business domains.

These SOA-based systems show that implementing SOA with WS technology has been a trend in SOA adoption into IS development including in education institutions. Usually, WS technology standards include Web Services Description Language (WSDL), eXtended Markup Language (XML), Universal Discovery, Description and Integration (UDDI) and Simple Object Access Protocol (SOAP) (Erl, 2005; Hayward, 2005). Most developments use WS technology, SOAP, XML, and Java programming language to develop the interface agent of SOA (Mok & Fong, 2008) so that could be centralized their systems. Besides, WS is widely accepted as an architectural style for IS (Nikayin, 2009) and it supports direct interaction with other software agents using XML-based messages exchanged via the internet protocols (Booth et al., 2004). It builds on a number of open standards, particularly on XML to tag data, SOAP to transfer data, and WSDL for service interface descriptions (Alonso et al., 2003; Umapathy & Purao, 2007).

In fact, WS is better than other technologies or middleware protocols since it supports direct interaction with other software agents using XML-based messages exchanged via the internet protocols (W3C, 2004). On the other hand, a design of a system with SOA solution planning is very useful in exchanging data efficiently. Most of SOA implementation are used together with WS technology to support the integration solution (Pansa, Walter, Abeck, & Scheibenberger, 2010) rather than implemented with CORBA and DCOM. This is in line with Papazoglou and Papazoglou (2008) who stress that WS is an independent infrastructure, loose coupling, and self container.

2.7 Existing SOA Models

Realizing the successful SOA adoption, embarking SOA requires a blueprint of SOA conceptual model or framework to be started in the early stage of IS development. Literatures have shown a number of SOA maturity models; SOA Maturity Model (SOAMM) by Sonic et al. (2005) and Service Integration Model (SIMM) introduced by Arsanjani and Holley (2005). They help clarify the SOA adoption. In addition, there are a number of SOA models for reference. One of them was proposed by Selamat & Kharusi (2009) as show in the Figure 2.6. The figure depicts that it uses Enterprise Service Bus (ESB) as the main transport to interoperable among heterogeneous IS.

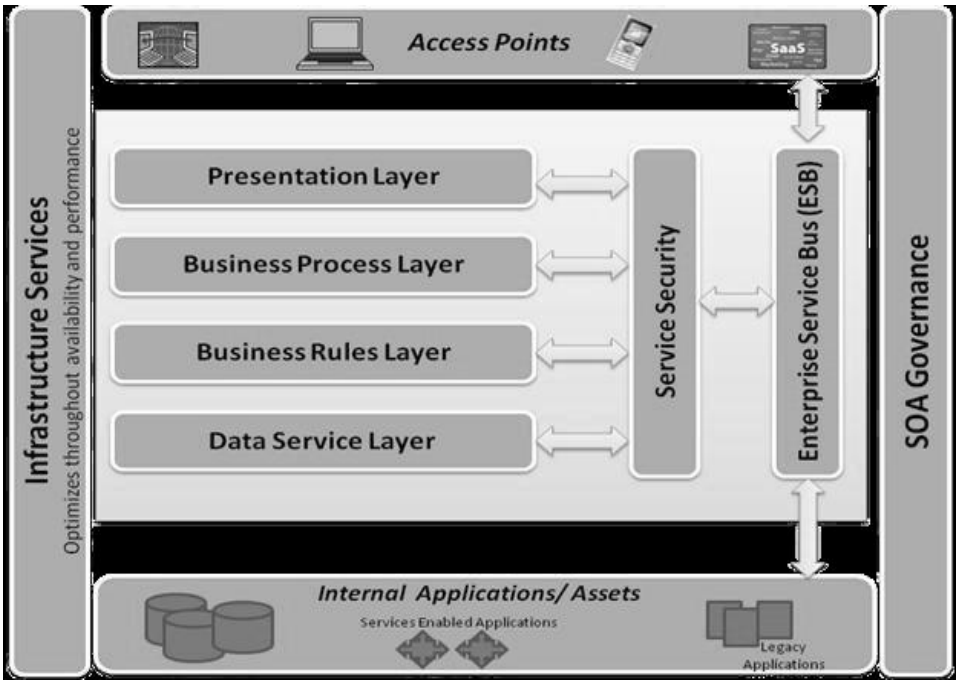

Figure 2.6: SOA Reference Model that proposed by Selamat and Kharusi (2009)

On the other hand, there is a conceptual model proposed for SOA-driven business transformation through the alignment of corporate computing resources by Roach, Low, and D'Ambra (2008) called Composing Access, Processes, Services and Information in a Conceptual Unified Model (CAPSICUM) which describes the SOA system designs and provides a mechanism for different system stakeholders to understand and participate in the construction of service enabled business processes. The model is proposed to support the SOA concepts of loosely coupled services and

real-time process orchestration. This is the first step in EA framework development for SOA, which is a framework for designing (March & Smith, 1995).

The CAPSICUM model that comprises four main layers; access, process, services, and information is depicted in Figure 2.7. It has been applied in a case study at National Revenue Agency by Roach et al. (2008).

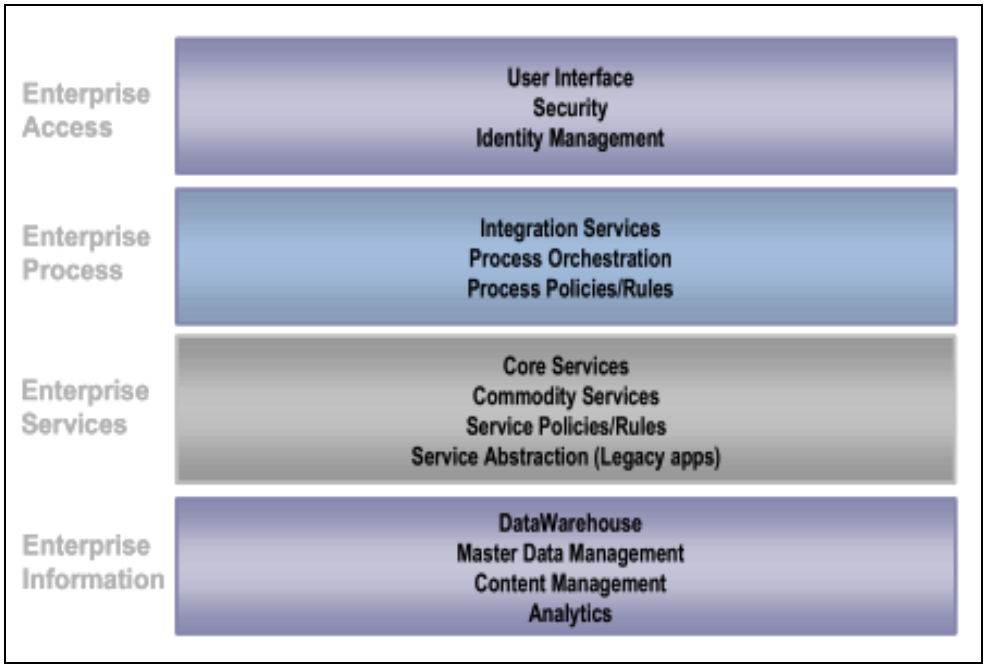

Figure 2.7: The CAPSICUM Model

However, SOA should not be seen as an ultimate solution for all IT problems. It has been argued that without a structured roadmap to implement SOA, the benefits which it offers are impossibly being realized (Huang & Hu, 2004; Biemborn, 2008; Adam & Doerr, 2008). It is evident that SOA projects, which in most cases span over a number of departments and enterprises, require an appropriate conceptual model as a guideline for implementation. In fact, some initiatives so far have failed to enable this alignment (Choi & Ramamurthy, 2011).

Recently, SOA has attracted attention of many academic and industrial researchers. Although the most popular SOA research is in its conceptual model in various domain of IS, most of the proposed conceptual models are still lack of empirical validation. It has been argued that good quality of conceptual models have to be proven by empirical validation before being successfully used in practice (Moody,

2005). Thus, based on the previous sections of reviews, a summary of SOA based system's characteristics are listing in the table below.

Table 2.3: SOA Characteristics

SOA Characteristics	(Bo & Kaihu, 2010)	(Mahmood; Alkhanak & Mokhtar, 2009)	(Leymann, Roller & Schmidt, 2010)	(Viering et. al., 20009)	(Erl; Pasatcha & Sunat, 2008)	(Yu & Ong; Muller et. al., 2009)	(Mason & Ellis, 2010)
Loose coupling	☑	☑	☑	☑	☑	☑	☑
Service based	☑	☑	☑	☑	☑	☑	☑
Reusable	☑		☑		☑	☑	☑
Real time data update				☑	☑	☑	☑
Accessibility	☑	☑	☑	☑	☑	☑	☑
Reliability			☑		☑		
Security		☑	☑		☑		☑

2.8 The Qualities of the Conceptual Model

Conceptual model is a high level description used as the basis for developing an IS. It could also be an abstraction of a model from a real proposed system (Robinson, 2006) which is developed and used in the early stage of development or simulation study. The content is highly necessary to design and apply the strategies and process. Robinson (2008) defined the conceptual model as

> *"a non-software specific description of the computer simulation model (that will be, is or has been developed), describing the objectives, inputs, outputs, content, assumptions and simplifications of the model"*

The quality of the conceptual model is the main factor of success implementation in practices. There are many (rigorous theory-based frameworks to speculative frameworks) conceptual models for IS standard that highlight the quality of conceptual model representations and process such as Conceptual Model Quality Framework (CMQF), Lindland, Sindre, and Sølvberg (LSS) and the Bunge–Wand–Weber representational model (BWW) (Nelson, Poels, Genero, & Piattini, 2011). This implies a sense of moving from the recognition of a problem situation to be

addressed with a simulation model to a determination of what is going to be modelled. Further, designing a model requires some considerations on appropriate design theories.

2.8.1 IS Design Theories

In general, the theory answers human needs to understand the world and to raise a body of knowledge that will help in understanding, explaining, and predicting things we see around us, as well as providing the basis for action in the real world. Gregor (2002) argued that the theory of design should be distinguished from other types of theory to allow its nature to check in detail. A special feature of the design theory is that it is normative and provides guidance (principles of design) for the action in the real world. These design principles are related to artefacts that include the system or subsystem models, artefacts and feature development methodologies and tools.

2.9 SOA Development Approach

Many parties have realized the importance of SOA adoption. However, to have a successful SOA implementation, a careful study and a good strategic plan is important and necessary because inappropriate planning will make SOA implementation costly and complicated. There have been many approaches in SOA development. In relation, Kontogogos and Avgeriou (2009) have analyzed the most influential approaches for SOA developments, in which they mixed and adopted the earlier approaches, for instance, Component-Based Development (CBD), Object-Oriented (OO), Business Process Management (BPM) and processes like Rational Unified Process (RUP).

Meanwhile, Allen, Higgins, McRae, and Schlamann (2006), and Jeng and An (2007) outlined the SOA development process into seven stages starting from service identification, service specification, service realization, service deployment, service execution, service monitoring and measurement, and service evolution and change. Another is ParticipativeSimulation (PartiSim) approach, which was applied in healthcare domain. They are six main stages in the framework as depicted in Figure 2.8.

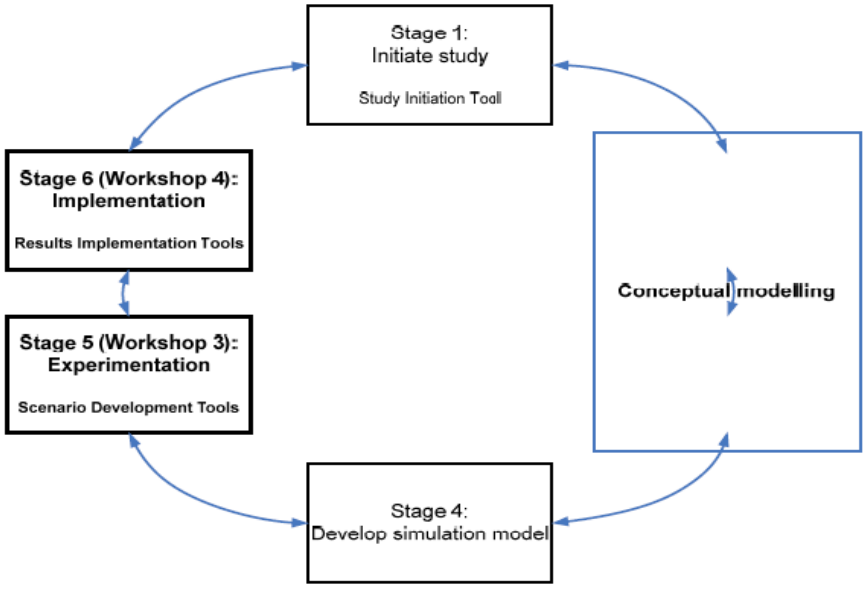

Figure 2.8: The PartiSim modelling framework and stages (Robinson 2004).

Nonetheless, the existing modelling framework by Robinson (2008) as shown in Figure 2.9 has been referred to by many domains such as game application, healthcare, and education. Seem this study will propose a conceptual model in education domain, it will be applied the simulation model because it found that more easy to read and understanding the process. Besides, to validate the conceptual model, it has to go through an empirical validation of prototyping experiments.

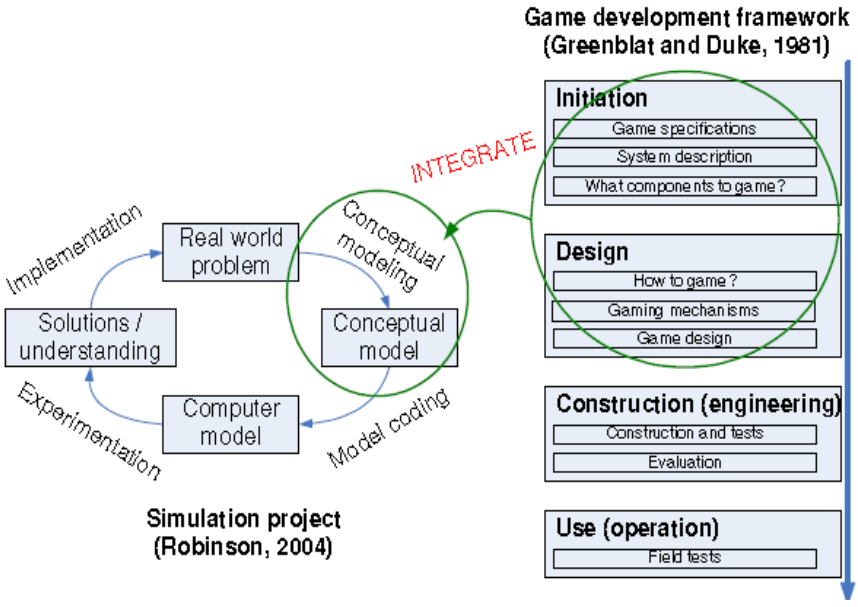

Figure 2.9: Simulation model (Adopted from Robinson (2008))

2.10 Validation Techniques for Conceptual Model

Many SOA researchers and professionals attend to the evaluation issues, in which most of the attempts are on a theoretical study instead of building a complete solution (Stojanovic & Dahanayake, 2005; Erl, 2007; Papazoglou et al., 2008; Kontogiannis, Lewis, & Smith, 2008). Thus, the evaluation is not enough strong to be implemented in real world case.

Several techniques could be used in validating the SOA based conceptual model. The strong technique is to test in real-world practices. However, Raghupathi and Kesh (2008) argued that testing SOA-based systems is challenging and is mostly carried out on simulations because the SOA-based systems normally involved in a large distributed system, which is built across multiple IS and enterprises.

In contrast to Raghupathi and Kesh (2008), this study decided to do an empirical validation in a case study to realize SOA in practices as stated by Moody (2005). It is sufficient because this study not only doing experiments of its logical flow and theoretical, but also its practical contributions. Besides, we could understand in depth the proposed conceptual model through the empirical validation.

2.11 Summary

Some previous works have proven evidences in applying the SOA concept in the heterogeneous systems that are difficult for integration. The literatures also discuss about SOA that is promised to have a big potential to be a better integration solution for SIS. These have been agreed by many SOA researchers and professionals where they had been adopted the SOA concept in their IS successfully. The required appropriate conceptual model as discussed in previous sections is very important for embarking SOA. On top of that, this chapter also analyses and compares the existing SOA conceptual models; the standard IS design methods as guides to produce the best result of a suitable conceptual model for SIS. Consequently, the next chapter discusses on the research methodology in ensuring the objectives as obtained in Chapter 1 are achieved.

CHAPTER THREE
METHODOLOGY

This chapter describes the research methodology of this study, including research design, data collection method, data analysis, and evaluation. It is not only a collection of methods to perform a research, but it is also a systematic way to solve the problem described in Chapter 1. The methodology in this study is designed to support the understanding on the issues of SIS integration in a heterogeneous environment using SOA to be more interoperable in a large distributed system in UUM. Accordingly, it is discussed by addressing the way this study constructs the conceptual model until the validity is achieved following the roadmap in Table 3.1.

Table 3.1: Summary of the Theoretical Relationship

Questions	Objectives	Outcomes	Methods	Validations
How to embark the SOA concept into SIS in UUM?"	To identify the requirements of embarking the SOA concept into SIS.	Requirements	1. Document study 2. Interview SOA Experts & SIS Stakeholders	Analysis
	To construct a conceptual model of the SIS embarked with the SOA concept.	Conceptual model	1. Consolidation of previous conceptual models 2. Modelling conceptual model to be incorporated with SIS 3. Expert reviews	Experience
	To validate the proposed conceptual model through empirical experiments.	Prototype	1. Proof of concept (Prototyping experiments)	Empirical validation of case study

3.1 Design Research

This study applied qualitative designs, which are case study and experimental techniques. The following sections described more details the techniques involved.

3.1.1 Case Study

This purposive study aims at overcoming the repeated tasks and integrating heterogeneous IS by using SOA concept. A conceptual model has been proposed, and it is more than statistical significant, so it could be considered to conduct a case study (Flyvbjerg, 2007). In experimenting the concept, this scopes' study is focusing on a small number of IS at a university rather than involving all IS in all universities on an anticipation that all IS in universities are homogeneous. Hence, experimenting the concept in the selected heterogeneous IS in a university could be sufficient as a proof. The case study provides in-depth understanding and it needs explanatory analysis (Klein & Myers, 1999) in understanding SOA and SIS with minimum requirements to solve the issues regarding SIS not highly interoperable systems. This has been the basis for adopting experimental case study besides it is investigate in a specific case (Zainal, 2007).

3.1.2 Experiment

The experiment method was carried out to achieve the third objective of this study, which is to validate the proposed conceptual model based on the SOA concept through empirical experiments. Additionally, embarking SOA into SIS in a large distributed system should be done incrementally so that if any failure happens, it is to not too severe and not affecting the current activities (Shull et al., 2002). Therefore, in this study, the best strategy is to do experiments in a small sample of SIS as a case study to produce a guideline to embark SOA into SIS.

3.2 Data Collection Techniques

Fact-finding techniques were used including document study (Whitten et al., 2001) and interviews (Sekaran, 2009). At the initial phase, this study reviewed on a collection of related journals, books, proceeding papers, technical reports and other

resources in the academic boundaries as a means to get the basic idea of the existing SOA frameworks or conceptual models for adoption into SIS and defining its requirements. Then it continues with an exploration on the documents describing about the selected SIS specifically ASIS, LZS and Library system from the Computer Centre of UUM.

This study employed a qualitative approach since the data were gathered in the form of words, pictures, model diagram and description where these all provide a rich and deep description about the ways to propose the conceptual model (Hartley, 2004). Further this study interviewed experts and stakeholders in the exploratory phase as suggested by Kenneth (2004). The interviews were aimed at understanding in depth the users' requirements and business process. The interviews' forms were conducted in unstructured and open-ended format, specifically involving stakeholders who involve with SIS management. On top of that, it is important to know the current situation of SIS and their issues or problems in more detail. Several interviews with SOA experts from other universities and IT industry were also carried out to ensure that the data are unbiased and accurate. The interviews questions given to the SOA experts are open-ended as listed below.

i. What is your opinions about the IS issues?
ii. Could you explain on details what actually SOA is about?
iii. What is the architecture?
iv. From your point of view, what is service?
v. How to build a business application by using SOA concept?

All the data were then analysed using content analysis to generate a conceptual model of SIS with SOA concept. The results of the interviews will be discussed in Chapter 5.

3.3 Content Analysis

This study explores the current architecture of the selected SIS to be modified into SOA-based system to get the idea for reducing repeated tasks in managing SIS in the future. Besides, the data gathered from interviews and document study was used to solve the problem. Specifically, data related to SOA is used to answer the first

research question stated in Chapter 1 regarding the requirements of embarking SOA into SIS and also the second research question on whether the gathered data especially the technical steps are sufficient to be incorporated into SIS conceptual model.

3.4 Conceptual Model Construction

From the content analysis, the requirements and data gathered will be used to construct the conceptual model. From the literature reviews section, a simulation model by Robinson (2008) will be used in the study. There are four phases involved as follows.

i. Real world problem
ii. Conceptual model
iii. Computer model
iv. Solution/understanding

From the real world problem, the researcher will analyze the problem and requirements. After required the needed data, conceptual modelling will be created. When the proposed conceptual model has been verified by the experts, the computer model phase can be implemented. A model coding will be run and tested to decide the best solution. After everything becomes validated, the solution is ready to implement in the real world.

3.5 Evaluation of Validity

To verify the accuracy of the proposed conceptual model, the expert review technique was carried out. From the experts review, all suggestions for improvement were added and followed with a better conceptual model. Thereafter, a validation was obtained by implementing the prototypes that used agile method. Three different prototypes were developed to validate the proposed conceptual model, which is useful to integrate heterogeneous IS. The prototypes developed by using several software like Spring Source and different type of databases; MySQL, PostgreSQL and Oracle XE to test interoperability function of SOA concept. Additionally, the

successful prototypes have also been evaluated by the application consultants from IT industry and stakeholders involved in the university.

3.5 Summary

Having carried out activities explained in the previous sections, this study merged to answer all the research questions and achieve the objectives. In conjunction, Figure 3.1 maps the methodology phases and activities with the outputs that supposed respectively.

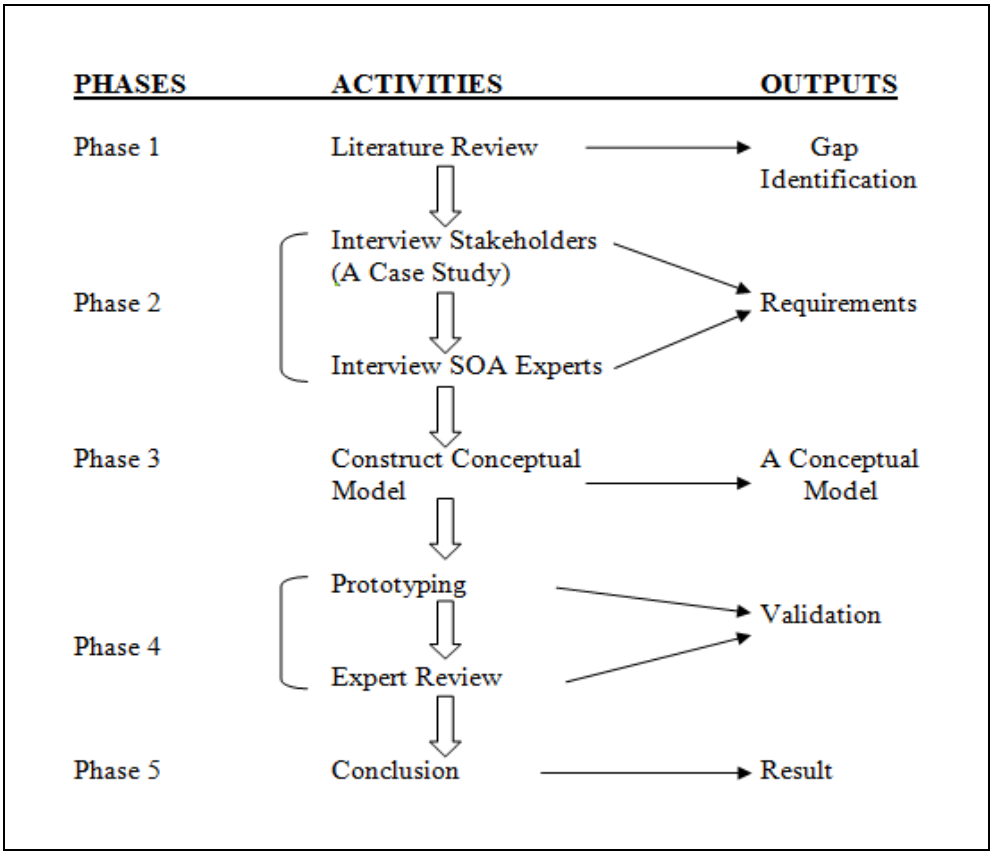

Figure 3.1: The Phases of Research Methodology

CHAPTER FOUR
ANALYSIS AND SYSTEM DESIGN

4.1 Introduction

This chapter describes the details about the data analysis and design of the conceptual model. From Chapter 2 of reviews, it had demonstrated that the trend of SOA adoption is normally related to three quality attributes i.e. interoperability, flexibility, and modularity, which currently becomes the main concern in the adoption of SOA concept into IS development. This could be a guideline for IS development for integration in universities. In fact, that is really motivates this study in the beginning. The intention was driven by the needs to solve system integration issues in the heterogeneous environment and will be discussed in this chapter.

4.2 Fact-findings Analysis

The unit of analysis in this study is an organization with three different IS, which are LZS, ASIS and Library System as a case study. The documents of the three systems were obtained from UUM Computer Centre. Several documents like ASIS and LZS modules documentation (include their system requirements, model and architecture), which are related to SIS were analyzed. In supporting the documents, previous literatures are needed to help the researchers understand more about SOA.

4.2.1 The Consolidation of SOA Conceptual Models

The review of literatures in Chapter 2 has identified the main requirements to enable SOA-based system. Table 4.1 depicts the main SOA components with its principles.

Table 4.1: The Main SOA Requirements

SOA Principles	SOA components
Reuse Loosely coupling Capsulation/Reliability Interface/appearance strict definition Dynamic nature/Accessibility Self-describing Open components Flexibility Interoperability Services based Modularity Highly agile Real time data updated	-Service provider -Service registry/ directory (UDDI/ebXML) -Service requestor/ client/ consumer

The main SOA components stated above had been identified from the SOA conceptual model. On top of that, several elements and other components also play important role in succeeding the SOA based systems. Figure 4.1 depicts the consolidation conceptual model regarding to the discussion in Chapter 2.

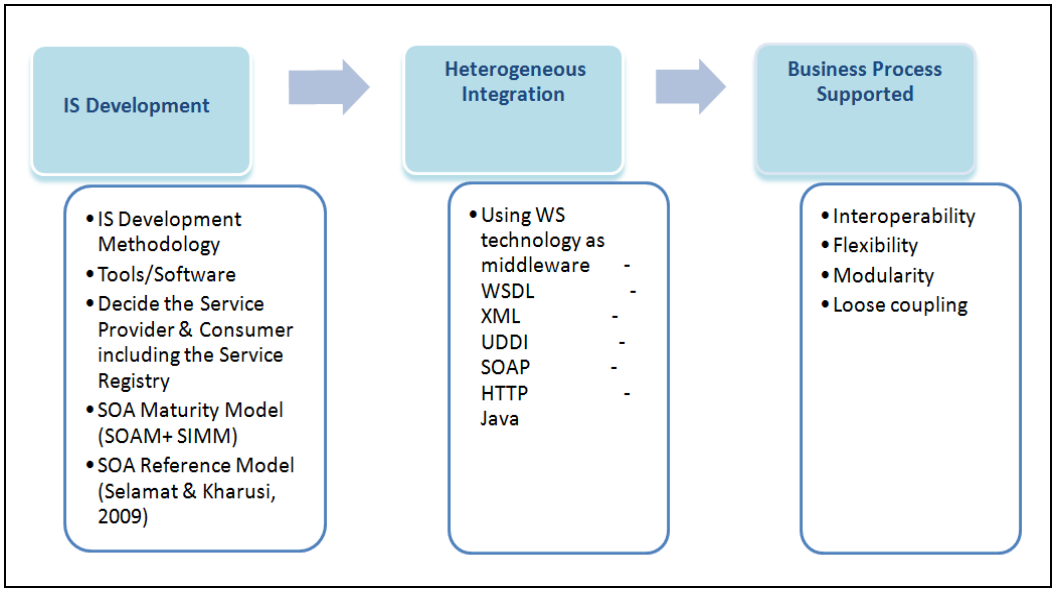

Figure 4.1: Conceptual Model for SOA Requirements (Own Work)

4.2.2 The Existing SIS Architecture

The main systems to SIS are depicted in Figure 4.2, which represent the core components in SIS architecture. It mainly relies on replicating certain parts to develop the prototype of SIS. The figure depicts SIS architecture with four main layers; front-end access layer, common services layer, data access layer, and infrastructure layer.

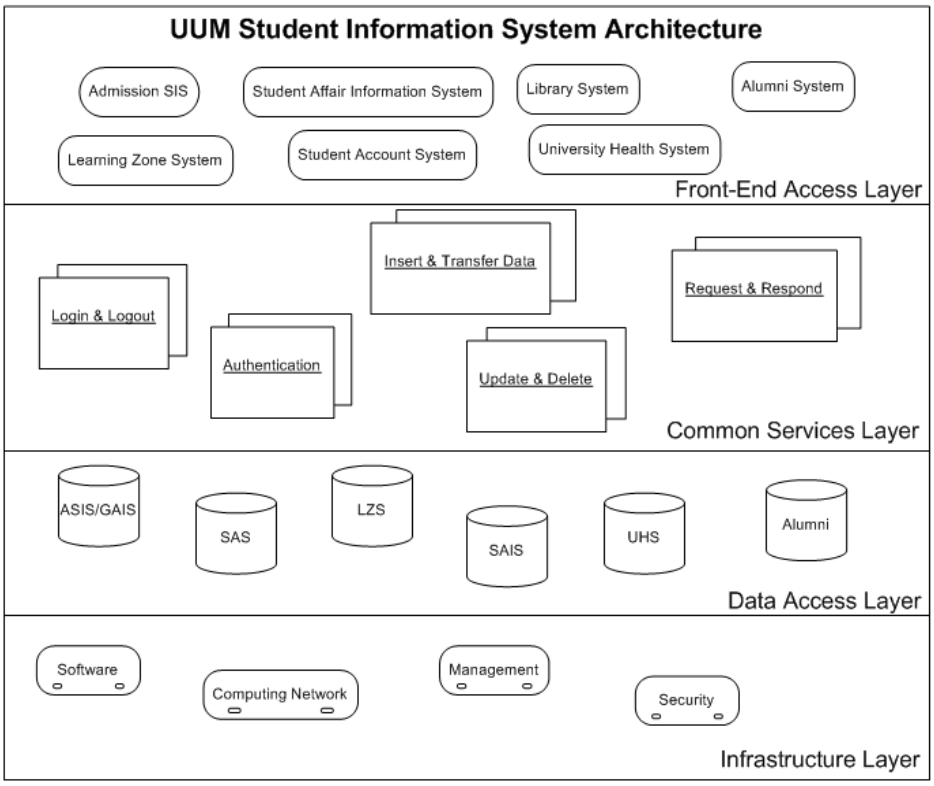

Figure 4.2: SIS Architecture of UUM Systems

a) Front-end Access Layer:

This layer refers the access interface that end users interact with SIS. It is considered the visible part of SIS, where all access to the systems' services can be achieved via interacting with this layer. It includes applications such as Admission, Student Affair Information System, University Health System, Alumni System, LZS, Library System as well as Student Account System.

b) Common Services layer:

This layer provides front end layer service with services that commonly needed by e-Services, such as Login and Logout, Authentication, Insert and Transfer Data, Update and Delete, and Request and Respond services. For the purpose of login and logout, it needs the authentication service to authenticate matric number or identification card number to access services against a single authentication repository, such as service is not incorporated in the front end systems, but rather developed as a common service to be used by front end system. Also this layer provides insert, delete, update, and transfer capabilities to the systems, particularly for managing their database. For transfer service, an update data from a database into another type of database, it is only valid among the similar type of database.

c) Data Access layer:

This layer locates database and access gateway, either centralized or decentralized. Front end services rely heavily on this layer. As an example, LZS service requires access the data from different sources i.e. ASIS, PERSIS, and GAIS, which virtually its central database.

d) Infrastructure layer:

This layer includes physical and low level software components, such as UUM private network, operating system and services as well as management and security systems. These components interface the networking devices and functionalities such as hosting and collaboration services, firewalls, and intrusion detection and prevention systems. The private network is the core element in this layer because of its interconnection capabilities for the departments' locations. This is because part of the inter-university traffic should be carried over a private, independent, and secure link. The software parts of this layer include the operating systems and their low-level services such as web hosting and email provider, database hosting, and systems and network management.

The content analysis identified the existing service portfolio at the service provider's side to understand the policies and processes already in place and which need to be introduced and implemented so that it could be more flexible in integration the

heterogeneous IS so that task repeating could be reduced significantly. The overall SIS architecture is not fully interoperated, and parts of it still need to be realized. Also the communication between layers is not well defined in terms of access protocols or standards. Hence, SOA can be used to provide a standard way of interoperability between SIS components, both software and hardware-based.

4.3 Data Analysis for Interviewing

This content analysis activity encourages a radical view of process redesign and support the reengineering of the business processes. Its main objective is to propose (reuse) the functions of the business processes in new composite application. Several interviews had been conducted with stakeholders of SIS in UUM Computer Centre. This is aim to insightful understanding about the heterogeneous IS in UUM. At the same time, several interviews also conducted with SOA experts to get more information about the SOA concept and its implementation.

4.3.1 Interview with SIS Stakeholders

The interviews revealed wealth information about IS in UUM, specifically about SIS. Obvious information that is related to this study is on its heterogeneous environment with various types of databases, programming languages, and operating systems. In conjunction, Table 4.2 exhibits the differences.

Table 4.2: The Current Heterogeneous SIS in UUM

System	Operating System	Programming Language	Type of Database	Data Update From
ASIS	Linux	JSP	Sybase	Manually Data Entry
GAIS	Linux	JSP	Sybase	ASIS
Alumni System	Windows	PHP	MySQL	Manually Data entry
LZS	Windows	PHP	MySQL	ASIS, GAIS. Manual Data Entry
Library Systems	Windows, Linux,	PHP, VB, JSP,	MsSQL, Informix	Manually Data Entry, other library systems, ASIS, GAIS
University Health System	Windows, Linux	VB, Power Builder	Sybase	ASIS, GAIS
Student Affairs Information System	Linux	JSP	Sybase	ASIS, GAIS, Student Account System. Manually Data Entry
Student Account System	Solaris	JSP + Power Builder	Sybase	ASIS, GAIS, Manually Data Entry

The heterogeneous IS created challenges in performing smart system integration. For instance, ASIS was developed using Sybase database and Java Script Programming (JSP), whereas LZS is developed using Hypertext Pre-processor (PHP) language and MySQL database. Both of the systems are related to each other, for example, the data in ASIS are used by LZS. Consequently, due to the different technologies, the stakeholders also called as the person in charge face challenges in updating the data from ASIS to LZS. The business requirements for SIS need to be defined ahead before presenting the proposed SoSIS conceptual model. According to the interviews, the person in charge at each SIS; ASIS, LZS and Library System stated that they need a smart integration system so that real time data update can be performed. The current IS could not automatically integrate across different programming language and database. Besides, the problems (as described in Section 1.2) like repeated tasks, wasteful data storage and cost of operation could be reduced. Although there is a need to integrate system, however, they have limited guides how to implement SOA-based systems appropriately into those IS.

4.3.2 Interview with SOA Experts

The purpose of the questions is to seek opinions about issues in IS development. The interview had been conducted with two SOA expertises from academician of different Malaysia public universities and two IT practitioners in industries. The results yields from the SOA experts' interview are summarized as follow in standardized open ended interview questions format.

1) Opinions about IS issues:

The problem in IT always involved consideration to improve the IS management, while the existing layers of IS architecture will be added from time to time based on user requirement. As the result, the architecture becomes flake of layers and it will be difficulties to maintain since its business processes and IS already merged, in which is hard to separate and need more cost for the maintenance.

2) What actually is SOA?

The second question is to ask the experts about their opinion of what is SOA. As summary, the services oriented purpose is to fix the layer of the legacy architecture

to be single sign on. SOA is a journey of architecture to align IT and business gap. An SOA expert said that to bear in mind, that SOA is not an approach, project, product or methodology, instead SOA concerns with the business process, then the system as referred to Schmelzer and Bloomberg (2006), SOA is defined as the component in architecture must be flexibility, robust, unbreakable, and reusable. This is because its interface design is standard and robust. E.g: Lego (see how its component of design can be standard for all and robust since the design is interoperability. Web service is one of interface pattern or method as simple as Lego; it can be plug in because the standard interfaces. SOA can be a small project and when involved enterprises, it called big project.

3) What about the architecture?

This question is to seek the definition of what is architecture. The definition of architecture is a design for a single purpose (e.g: building design from an architect). Meanwhile, total architecture will involve business processes, people, information, and system. They have become so intertwined in the modern enterprise that you can no longer design them independently.

4) Service term in SOA from their point of view:

Since there is like a common word of service, this question try to clarify what is service actually in SOA. An expert said that everything existing component should be service. Service is where somebody makes a request, and the services provider will provide the services (respond). Then here the process is not important again (user/requester should not see the process). Nowadays IS in organization is moving toward service orientation. Figure 4.3 depicts the service concept.

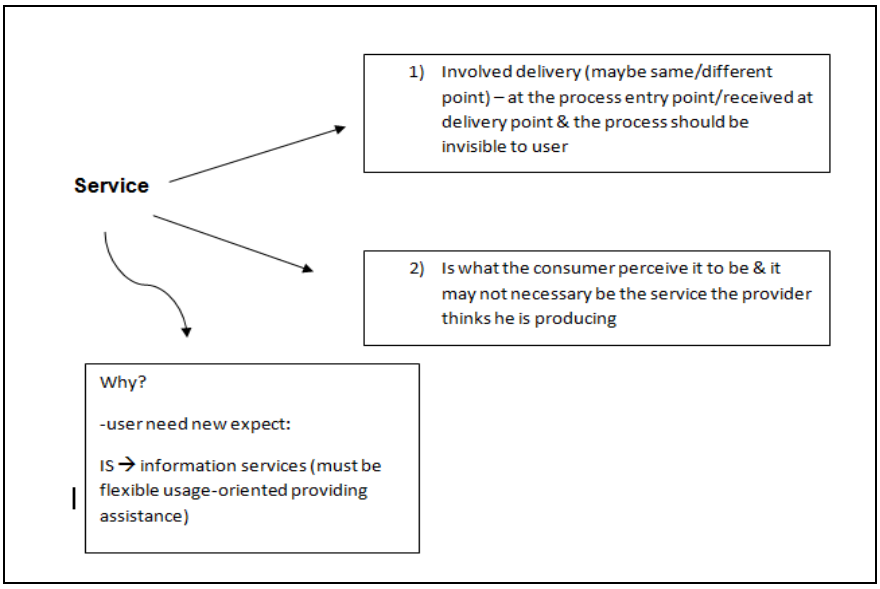

Figure 4.3: Service Concept

5) How to build a business application by using SOA?

This question is trying to get information and the experience of the experts if they have been involved in any SOA-based project development. To build an application that implement business process gives a similar definition to build business architecture which is required (1) set mission for the outcome, (2) specify services that necessary and (3) implement business process (modelling). It is recommended using top-down approach methodology so that the bottom one will known by achieved the top one first (its mission, vision and goal). Figure 4.4 depicts the top-down approach, in which the suggested methodology is to be used.

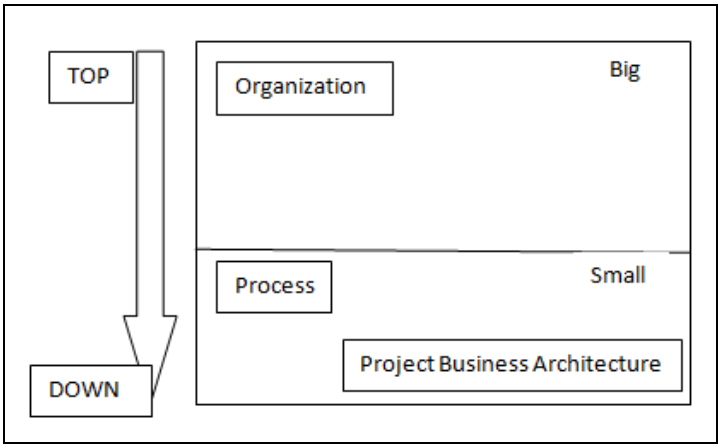

Figure 4.4: Top-Down Approach

6) Conclusion

As conclusion of the experts interviews results, SOA could have defined as a new approach to build IT system that allows business to leverage existing assets (for make sure it is services) and easily enable the inevitable changes required to support business. The SOA concept makes any process behind where need users to not care about its complicated process anymore.

SOA enables business to follow information technology by identifies the business services. Then to add or remove the component, it is up to customer's demand. Business process is a process flow of a service. The business architecture involves interactions in services (request). One function will be used in whenever process applicable (reuse) and can change something of services but it must be in a standard language. The results from the interview will help researcher to create a conceptual model that could be used in SIS so that fulfil all the needed requirements like interoperability and reusability.

4.4 SOA to use into SIS

In addition, the reviews discussed in Chapter 2 will help to decide what technology will be used to implement SOA in SIS. Hence, this study uses top-down approach in embarking SOA into SIS, in which the process begins with modelling its conceptual model as well as its framework before going to the prototyping. For the purpose of enabling various types of databases to communicate, loosely coupled components should be used. Then, the SOA concept comes as a service-based to interpret the various data among the heterogeneous IS. This explains that the focus of this study at Data Access layer of the architecture in Figure 4.2. It is an important part in the university's system because it has a vital role in building and integrating all the university's IS.

Web services (WS) technology will be used in the SOA implementation. The fast adoption of the WS emerged from the maturity of XML-based WS standards such as SOAP and WSDL (Alonso et al., 2003). Various characteristics of SOA such as loose coupling and services based can be supported by WS technology. The WS also support the basic of SOA requirements for developing the prototypes. There are three

main roles that use standard messaging, which are service provider, service registry, and service consumer (Papazoglou, 2003). In this standard, the services are published by the service provider to the service registry, which is a repository that holds services interfacing information. The service consumer will search the required services at the service registry, and will find the data or information with the service provider.

4.5 The Design Phase

As the first step in designing the SOA-based SIS, the conceptual model, which is named as Service oriented Student Information Systems (SoSIS), this study applied the theory for Design and Action (Gregor, 2002). The design decisions and design knowledge is meant to be expressed in the forms of design principles during construction of SIS model with SOA concept.

Practically, distributed systems that used SOA are dependent on certain architectural style. Hence, more styles that encapsulate the functionalities of the server-side as a joint service are necessary. Practically, joint service allows systems to interoperate on different servers. Hence, it can ultimately achieve data integration and information sharing.

4.5.1 Architecture for SoSIS

For a system to be flexible and efficient there is a need to access data from other related department's sources. The SOA concept comes as a solution to share and integrate the data among heterogeneous IS. Particularly, the focus of this section is to create architecture of SoSIS, which is an important part of SoSIS technical framework. As mentioned in Section 4.4, WS is used in this SoSIS to ensure the systems in the heterogeneous environment can interoperate. In conjunction, Figure 4.5 shows the proposed SoSIS architecture that is applied in enhancing the technical framework of SoSIS.

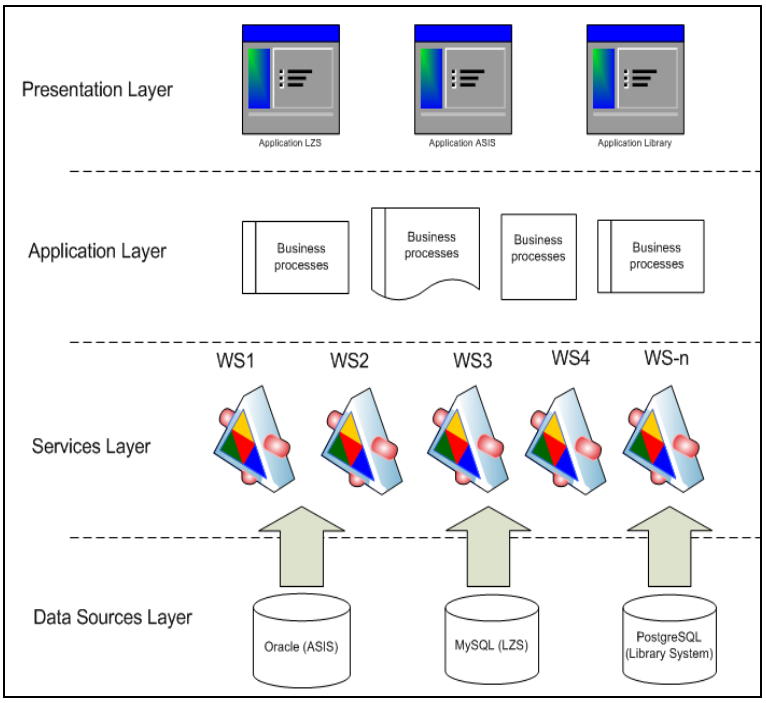

Figure 4.5: The Proposed SoSIS Architecture

4.5.2 Proposed SoSIS Conceptual Model

In this study, the focus is on works' proposing on an automated data update into different types of databases in several different systems. To enable various types of databases to easily communicate or connect to each other, the components should be loosely coupled, and ensured with high interoperability. Practically, the SOA concept comes as a service based to interpret the various data among the heterogeneous IS. Hence, there is a need to focus on SoSIS database model of Data Access layer, which is an important part of the architecture in SoSIS.

Having the requirement ready in the previous sections, the study proceeded with proposing SoSIS conceptual model and developing a prototype to explore the potential of SOA adoption. Different tools and standard technologies that support SOA functionalities were applied towards determining the suitable solution for implementation. SoSIS deployment diagram with the focus of ASIS and LZS is illustrated in Figure 4.6.

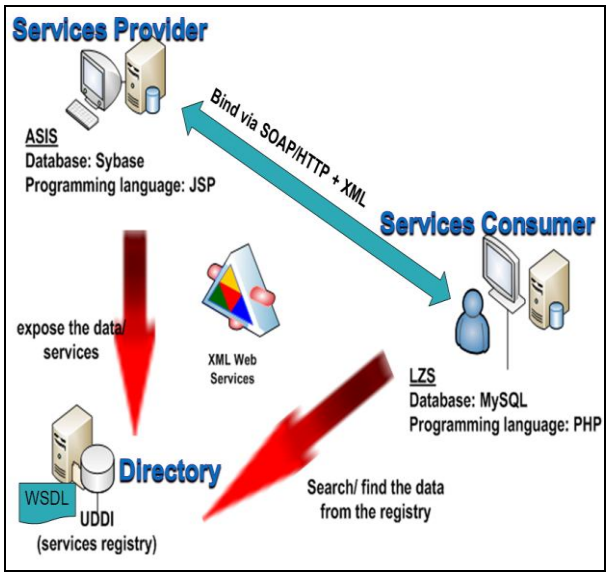

Figure 4.6: Deployment Diagram of SoSIS Integration

SoSIS was conducted to outline how a conceptual model achieves the interoperability and flexibility purposes. First, the flexibility is achieved by using standard Hypertext Transfer (or Transport) Protocol (HTTP) transport (as shown in the Figure 4.6) to carry messages between the web application in LZS and ASIS (either over the university private network or the Internet). The HTTP transport is generally allowed and not filtered by firewalls, in which in the deployment diagram, to carry out data from MySQL to Sybase, can be directly transferred with safe. Second, interoperability achievement is clear in this scenario because the web application and ASIS are database type independent, and so if the low level database that holds the Student Registry is changed from e.g. Oracle to MySQL, then change is not required either to the web application or to ASIS.

A conceptual model was created from SoSIS integration deployment as depicted in Figure 4.6. Practically, SOA characteristics specifically services, loose coupling, and interoperability were contributing to the valuable benefits that was discussed in previous sections in this chapter. In conjunction, to realize the conceptual model of SoSIS (Figure 4.7), different components are presented that constitute to the conceptual model. Each component would satisfy one or more requirement and leads to the achievement of the goals of the conceptual model.

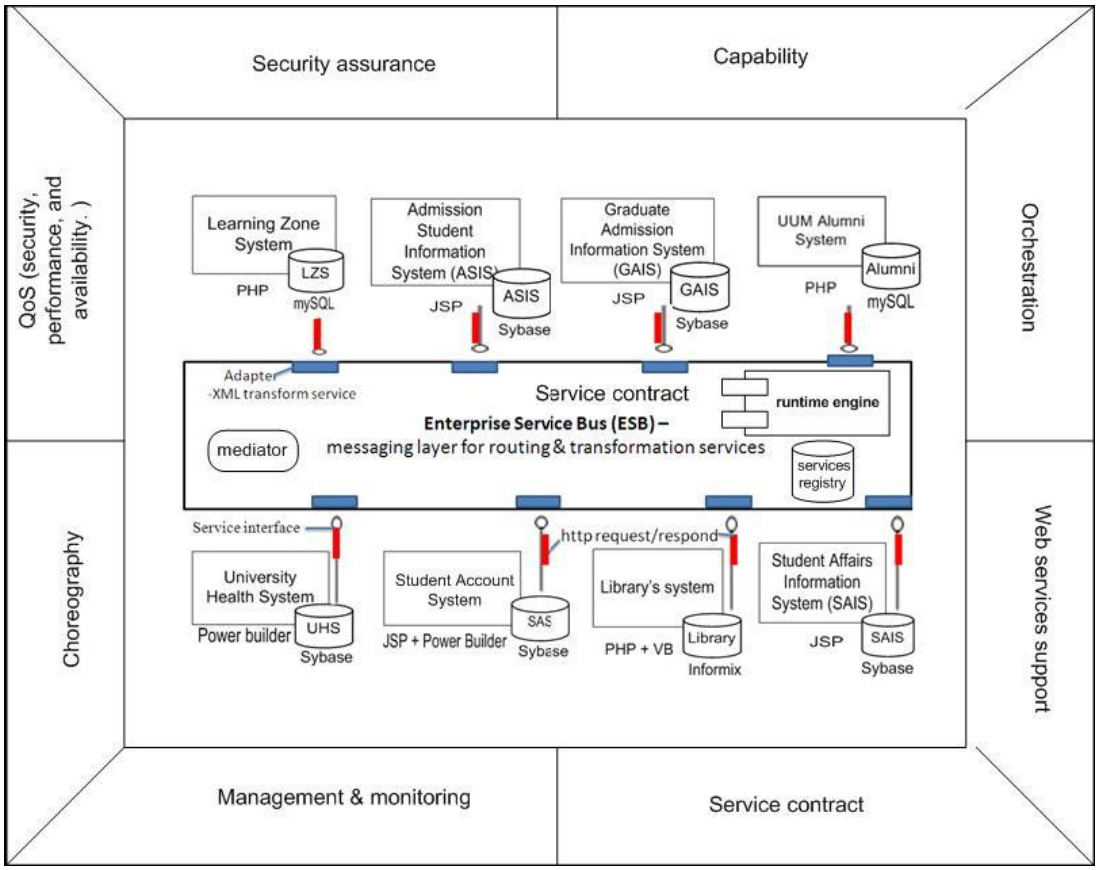

Figure 4.7: Initial Conceptual Model of SoSIS

The following describes the elements of the proposed conceptual model.

a) Enterprise Service Bus

Enterprise Service Bus is considered as the central platform of the integration between different WS, and provides routing and transportation features for WS requests, and it determines the service quality for the framework. It has been used and accessed by departments in the university via university's private network, as well as by departments outside the campus. Hence, this enables accomplishment of the reachability requirement. For this purpose, it includes a mediator as the adapters to enable different environments and languages to be found and bind the services as needed. Besides, there is a service registry, in which it is used to provide a search point of access to services and database definitions and metadata for all services provided by the central database in the SIS model. Practically, the registry is based UDDI.

b) Information systems in SIS

In SIS, there are eight main IS that require the information in ASIS and GAIS to be updated. However, not all the systems are built on similar platform and programming language as well as database. However, the use of the WS technology ensures that, all the difficulties to exchange data among the heterogeneous IS could be possible.

c) Security Assurance Service

This service insures that the security policies adhere to and achieve the security requirement in the conceptual model. It is invoked by different services to add a security layer to their functionalities, in which the security functionalities provided include authentication, authorization, and non-repudiation. In short, the service carries out the security requirement of the conceptual model.

d) Capability

The framework of SOA has to make sure that the system is interoperate and flexible. This is because the framework is focused on the heterogeneous systems and need to decide the software or tools which are suitable to implement the SOA concept into SIS.

e) Orchestration

When an application applies SOA in current era, they most probably use WS. In a large distributed computing like SIS, there are many IS operating with different functions. They probably provide services that are allocated in the services registry. Hence, the services have to be orchestrated with WS functions.

f) Web services support

Enable web services, well requires this study to use more than one tool to create different environments. Practically, the basic elements for a successful WS are SOAP, XML, and WSDL.

g) Service Contract

The policies and rules among the services fall on the services interface, specifically WSDL. In conjunction, it is very important to know who, where, and what a service is for.

h) Management and Monitoring:

The management service is used to manage and monitor the central database service bus, and WS. It collects metrics, and provides framework performance reporting capabilities. It has found that both management and monitoring requirements of the framework are achieved in this service.

i) Choreography:

Choreography, in a WS context, refers to specifications for how messages should flow among diverse, interconnected components, and applications to ensure optimum interoperability. Services communicate with each other by exchanging messages, which allows them to make or to respond upon requests. Upon the reception of a message, services react by executing some internal invisible processes, and possibly, responding to other messages. Choreography deals with describing such external visible behavior of services as message exchanges. In order to allow interoperation among services exposing different visible behavior, the means to map heterogeneous message exchanges is required. Choreography represents the outermost entity in the behavioral model. It describes the behavior of the answering service from the initiating party's point of view. It governs the message exchanges among the parties in a conversation

j) Quality of Service (QoS):

Each SOA service has certain quality of service (QoS) measures associated with in which include performance, accessibility, reliability, and security such as authentication and authorization, reliable messaging, and policies regarding who can invoke services. In detail, the interaction between the components is done through the ESB, which integrates the components and acts as the glue that tights them

together. It routes, transports, and formats the requests and responses of the services. It also provides service discovery through the registry.

4.5.3 Example Scenario of the Conceptual Model Usage

This section addresses a scenario of the use of the proposed conceptual model. A lecturer who uses the LZS would like to check his student's latest updated details in the ASIS Registry. He has to wait until the next day because the current system is not providing real time data. However, using the services based on SOA concept, the data are updated in real time data across different database. The lecturer, over the Internet, accesses the list of students registered in his class or subject section in the LZS using his login credential. Technically, the web application running in the portal would use SOAP messaging and transport to invoke the WS. Finally, the web application renders, formats, and presents the required information to the lecturer.

4.6 Summary

In this chapter the current scenario SIS and its requirements, the core part of the UUM IS is discussed in detailed. SoSIS solution is proposed that overcomes the shortcoming of the currently used that lacks of interoperability and flexibility. The discussion in this session explains that the conceptual model achieves its goals, which means it is good at interoperability, flexibility, and manageability. The interoperability is proven by allowing different types of database, meanwhile, the flexibility, which allows different ways for performing a specific task, is achieved by accessing the information services over HTTP transport which generally uses the port 80 which is normally not filtered by internet firewalls. Hence, the access to the central database can be both from the internal university private network as well as over the Internet. In contrast, the manageability, which provides the ability to control and adjust the behaviour of the system in response to various circumstances, is accomplished by having a metric, performance, and QoS as part of the logic flow in the management services.

CHAPTER FIVE
EVALUATION AND DISCUSSION

The evaluation of the proposed conceptual model had been done by the experts and through empirical validation. More discussions are presented in the following sections.

5.1 Expert Review

The experts review has been commenced iteratively as early as in the beginning of the conceptual model development. It has continued until the best result for improvement was obtained. For the first step after finishing the conceptual model structuring (as depicted in Figure 4.7), SOA experts (academicians) from two universities in Malaysia are referred. It was followed with some improvements on the conceptual model as suggested by the experts. Besides, this study also includes the SOA experts from IT industries to review as well. They were asked to comment the proposed conceptual model given in the Section 4.5.2 (the conceptual model referred to Figure 4.7) so that it could accept to validate conceptual model based on SOA. As a result, a new conceptual model was created and verified appropriately for embarking SOA into SoSIS.

Table 5.1: Result of Expert Review

SOA Experts	Comments
Expert 1	More description needs to add in understanding the conceptual model. Also good to add data warehouse concept in SOA concept.
Expert 2	Have to be cleared on the technical part so that readers can understand how to develop SOA in case to integrate different types of databases.
Expert 3	Better to redesign to show the flow of interaction process or in a framework.
Expert 4	Not bad in general but need to add one more conceptual model that has been narrow down the scope, which is at least involve the main SOA elements like a service provider and a service consumer for explaining how they interact each other using SOA concept.

5.1.2 The Revised Conceptual Model

Based on the comments and suggestions from the SOA experts above, several modifications had been done on the proposed conceptual model. Based on expert's suggestion, the conceptual model was redesigned to show the flow of interaction process on how the involved IS integrated with each other by narrowing down the scope of the three main IS. Some components in the initial model (refer Figure 4.7) were combined in a group of components' name and the diagram design becomes more simple and clear. The modifications are as follow:

1. The choreography, QoS and orchestration components in the initial model were categorized into Monitoring & Management component.
2. Security assurance is under security that contains all related elements with security.
3. Web services support was shown in the interaction process of integration, which is marked with number ①,②, and③in the Figure 5.1. In addition, the service contract is also in the web services concept.
4. To be more cleared on the technical part, the new conceptual model shows the layers from the proposed architecture in Figure 4.5 so that show the mapping of each layer to the main components.

Then the conceptual model was brought to the same experts to re-evaluate. In overall, the results for last round evaluation, showed that all the experts agreed and satisfied. In accordance, a new conceptual model was illustrated as shown in Figure 5.1.

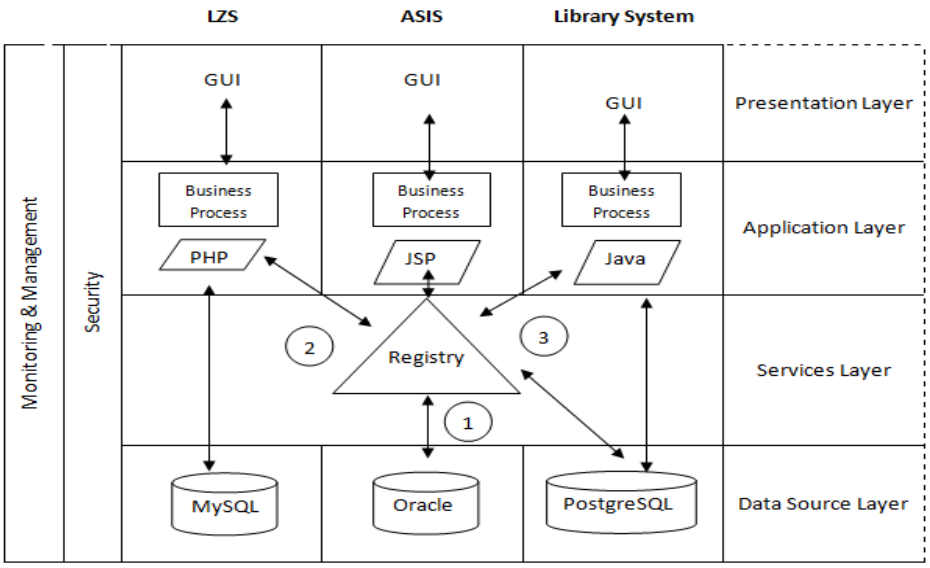

Figure 5.1: The Proposed Conceptual Model

The details description of the integration process including expose service component and the invocation has been explained as follows regarding to the number shown in the figure above (1, 2 & 3).

1. The process in the number one, ① shows WSDL used for publishing the service (data that will be shared). In WSDL, there is one/more service contract. The service contract will describe about services that they offered. For example in this case study, ASIS will expose certain student data depends on demand to the services registry so that another different application could be found easily.

2. Process at marked number two, ② depicted that in LZS, another database types and programming language used, which is MySQL and PHP respectively. As mentioned in the problem statement (Section 1.2), the real time and automated data update very crucial to make sure client/LZS's users get the accurate data efficiently. Therefore, LZS will invoke the required data from ASIS web services via interface provided used SOAP.

3. At the number three, ③ interaction process, ASIS and LZS can be assumed as legacy system and a new system of library, in which also have to use the same services from ASIS can reuse the service component in the ASIS web services.

5.2 Empirical Validation

After reviewed by the experts, the proposed conceptual model has also been tested empirically. In reference to that, the proposed conceptual model that had been verified by SOA experts was focused on a small scope, for a prototype to be developed and empirically tested with SIS. In conjunction, three different IS with different types of databases and programming languages were selected for validating the proposed conceptual model (refer Figure 5.1). All the prototypes have been developed successfully, and then run to test all the features and functions as well as verified as an SOA-based system by two application consultants from Malaysia who have experienced more than five years in dealing with SOA and WS development. The person in charge of three selected SIS (4 peoples) also contributed in this evaluation. The three prototypes developed were described in the following sections.

5.2.1 Prototype 1: Academic and Student Information System (ASIS)

ASIS prototype was developed as a service provider. It represents the main SIS in the university. It is built on Spring Hibernate and JSP programming language, and Oracle XE was used for its database. Students' data that are requested by other systems are exposed as WS.

This prototype is assigned to a specific staff (person in charge) as the administrator, who is authorized to enter and register students in the university (record student data). Meanwhile, the students' role is to add and drop intended subjects during the study period via this system. They can also update any data when necessary, like changing phone number, email, and home address. The data are later exposed as WS to LZS and Library system as their system requirement. In detail, Figure 5.2 depicts the flow chart of the developed ASIS while Figures 5.3 and 5.4 exhibit two snapshots of the prototype.

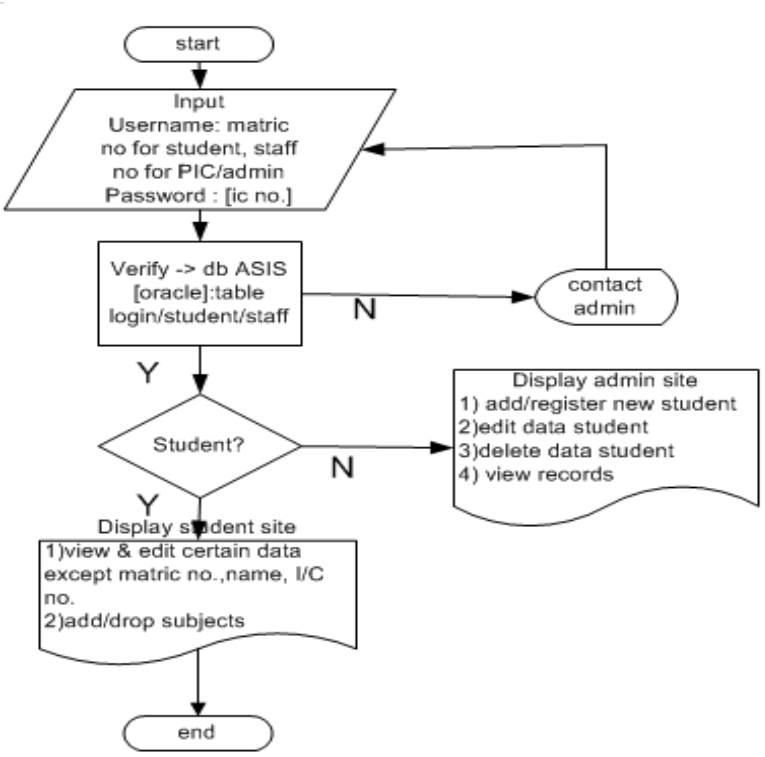

Figure 5.2: Flow chart of ASIS Main Functions

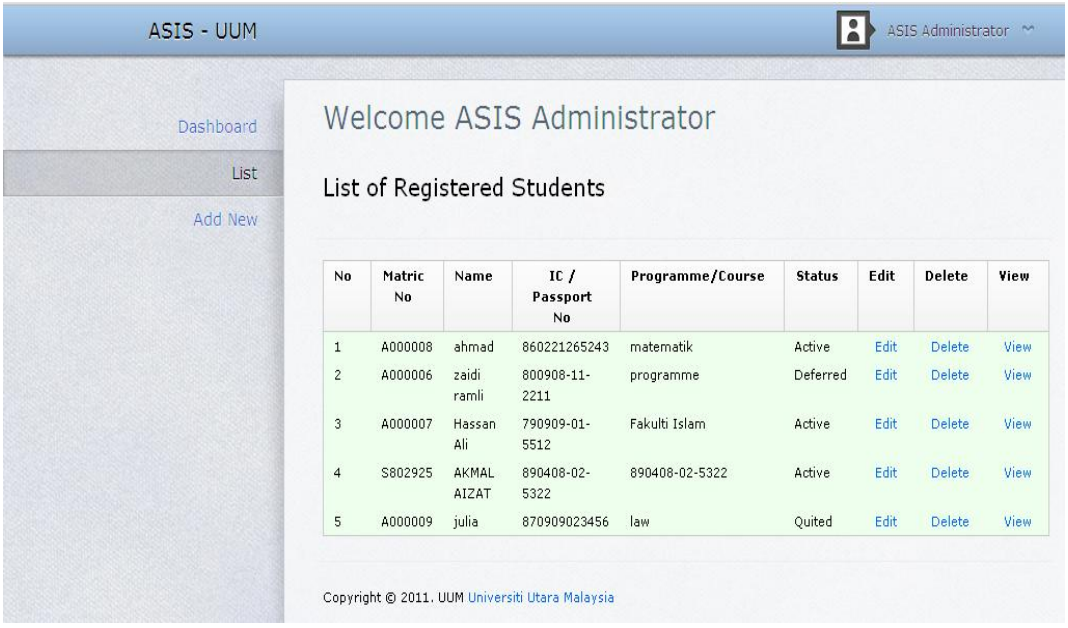

Figure 5.3: The Student List' Page

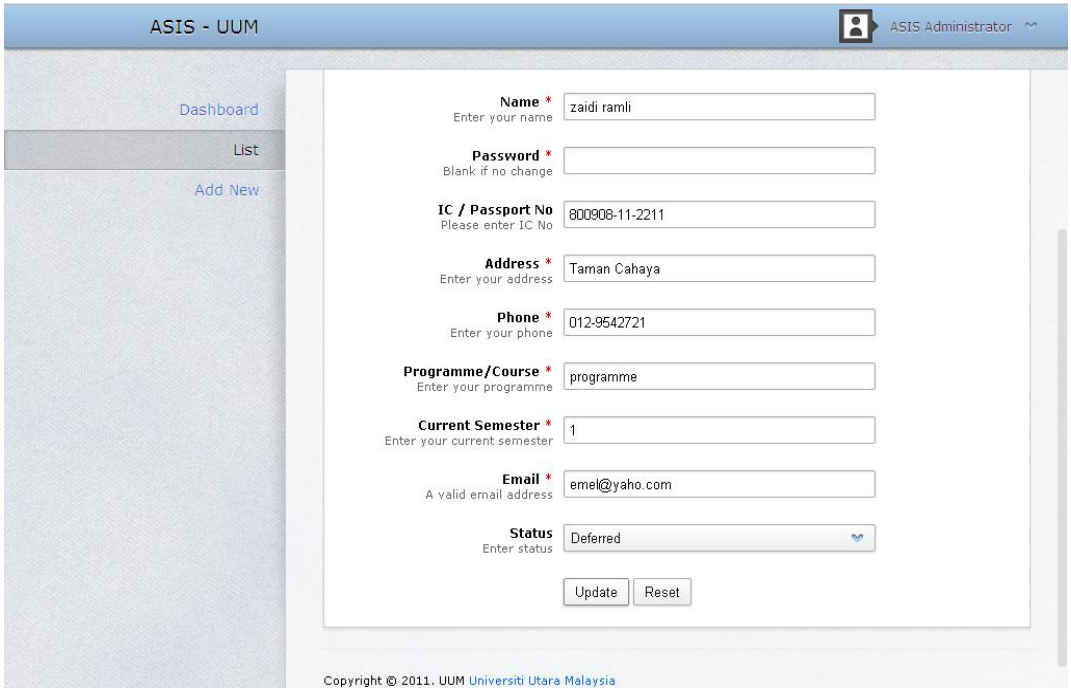

Figure 5.4: Online Form for Entering New Student Data

5.2.2 Prototype 2: Learning Zone System (LZS)

LZS prototype is built to serve the consumers (lecturers and students). It invokes the services of the required data to be displayed or to be updated into its database (MySQL). It uses Apache 2.2.8 and AppServ 2.5.10 as its server. Even though LZS is developed in PHP language, it can automatically load the required data from the Oracle database in ASIS on every single second (so it gets the latest updated data in real time). The detail of the prototype is illustrated in Figure 5.5. Meanwhile, two snapshots of LZS are depicts in Figure 5.6 and 6.7.

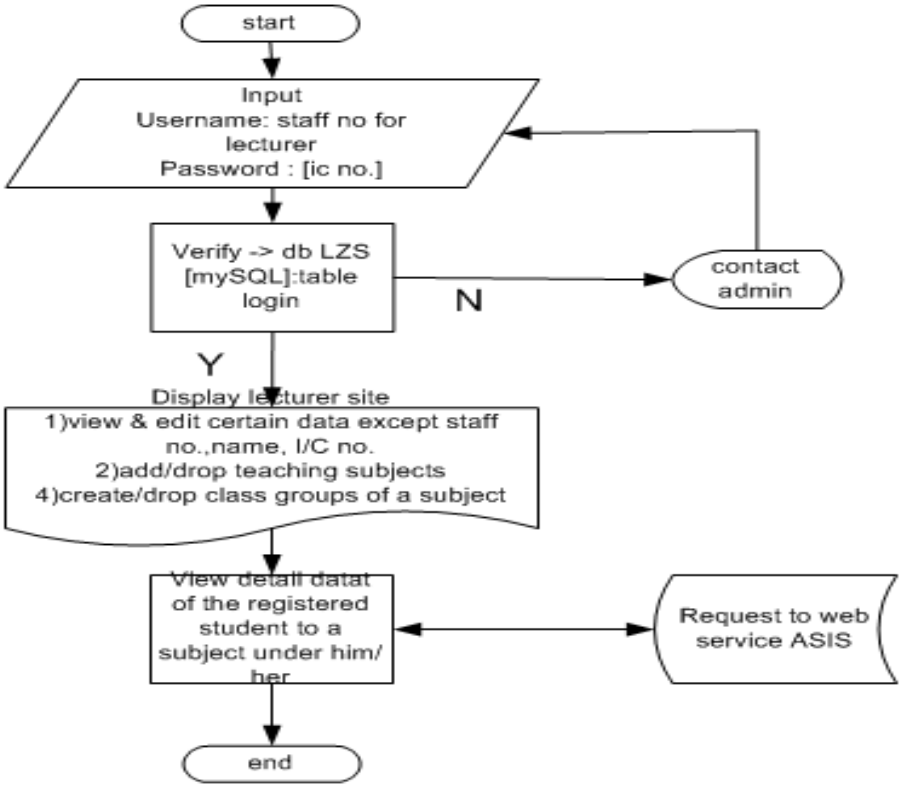

Figure 5.5: Flow chart of LZS Main Functions

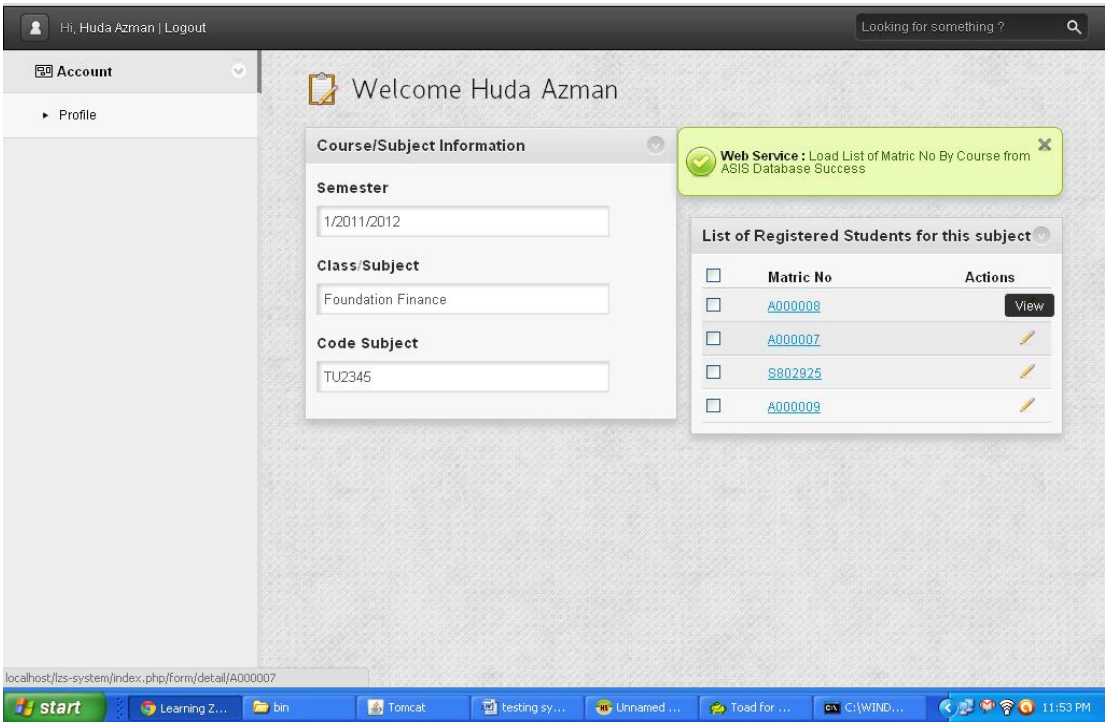

Figure 5.6: The Real Time Integration with ASIS

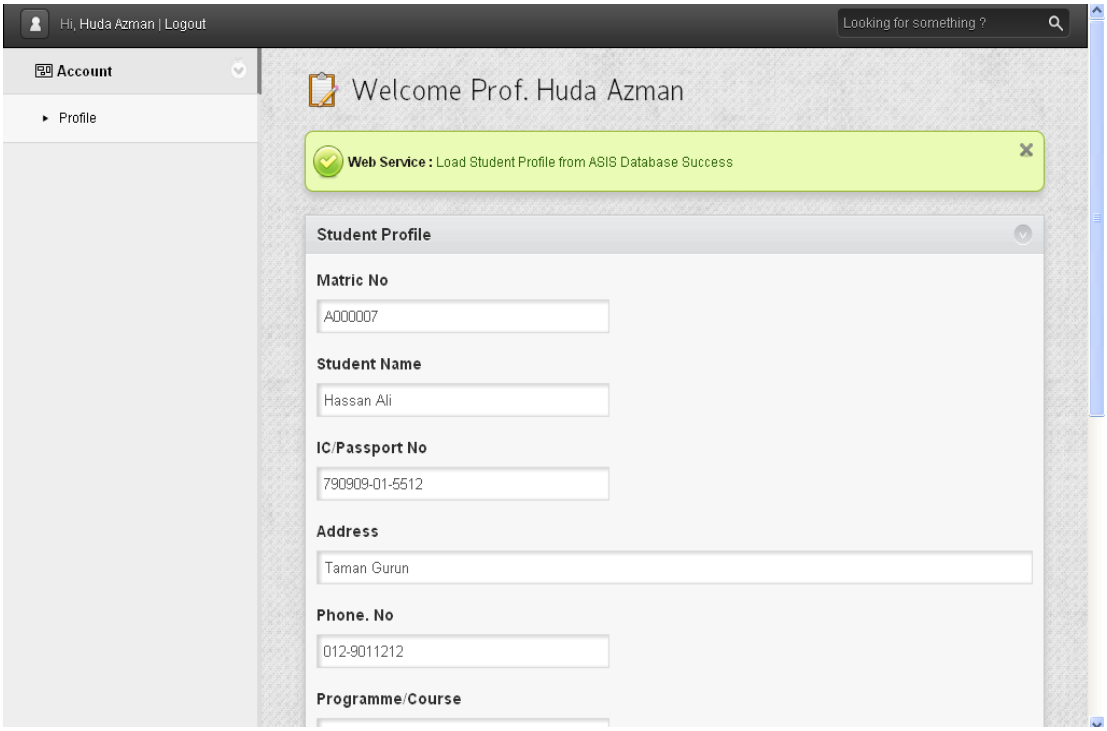

Figure 5.7: Student Profile from Lecturer View of LZS

5.2.3 Prototype 3: Library System

The data from of the WS in ASIS can also be reused to interoperate with the prototype for Library System. This prototype was developed using Java programming language and PostgreSQL for its database. The flow of the prototype is illustrated in Figure 5.8. Meanwhile, the interfaces are displayed in Figure 5.9, and Figure 5.10. It uses the service concept in updating its data from ASIS.

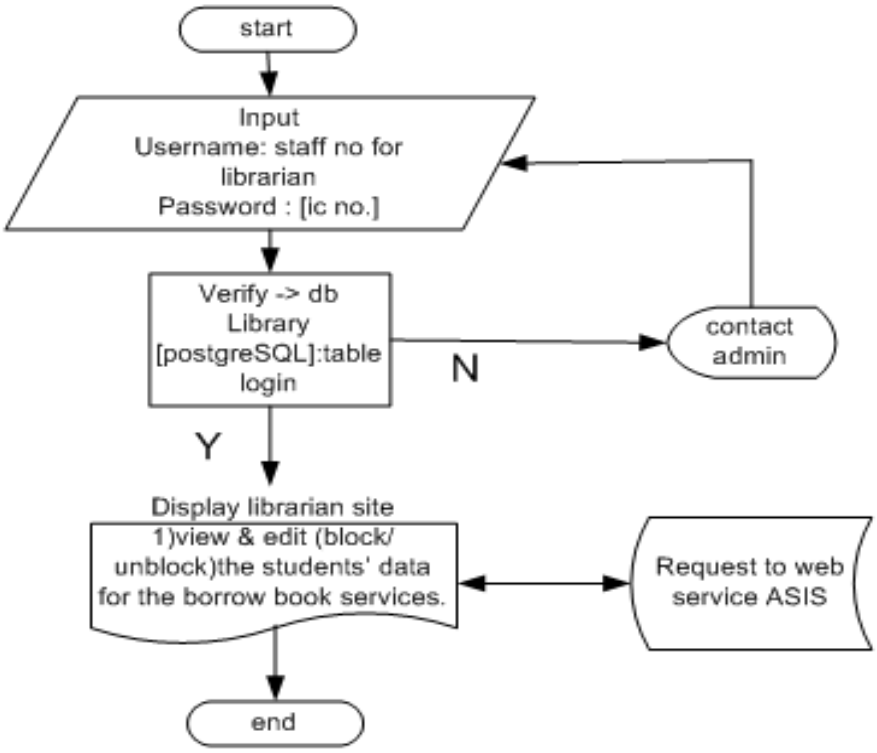

Figure 5.8: Flow chart of LZS Main Functions

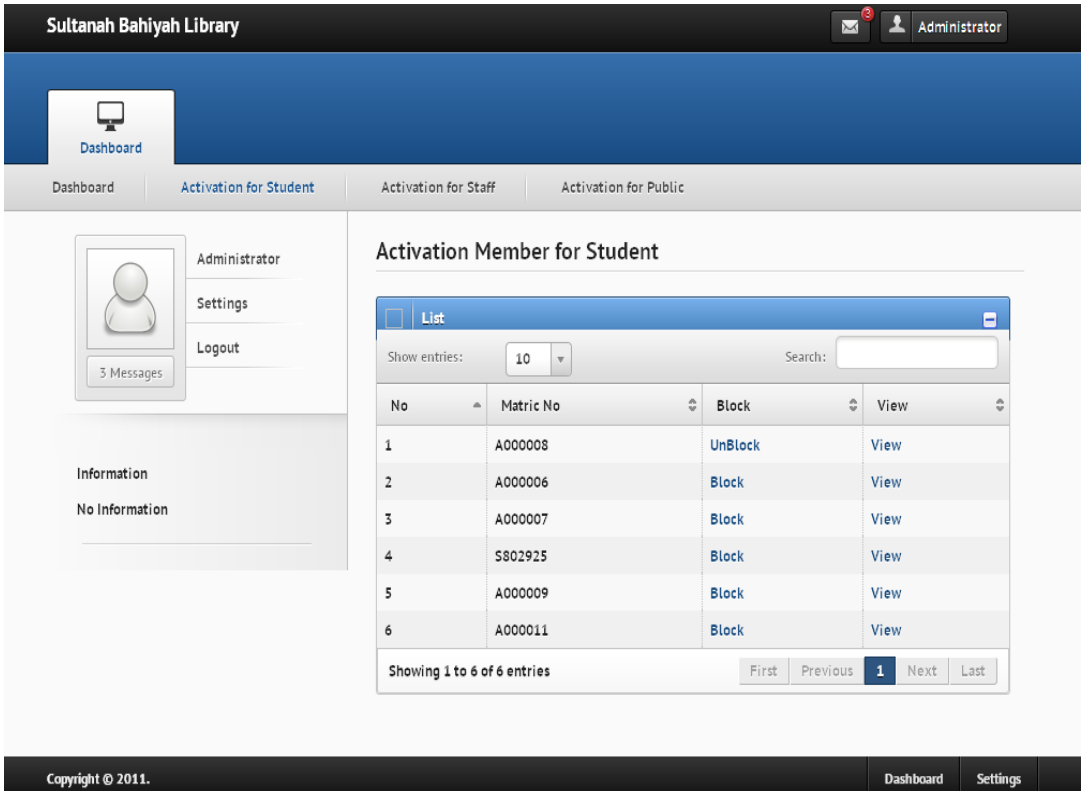

Figure 5.9: List of Library Members' Page

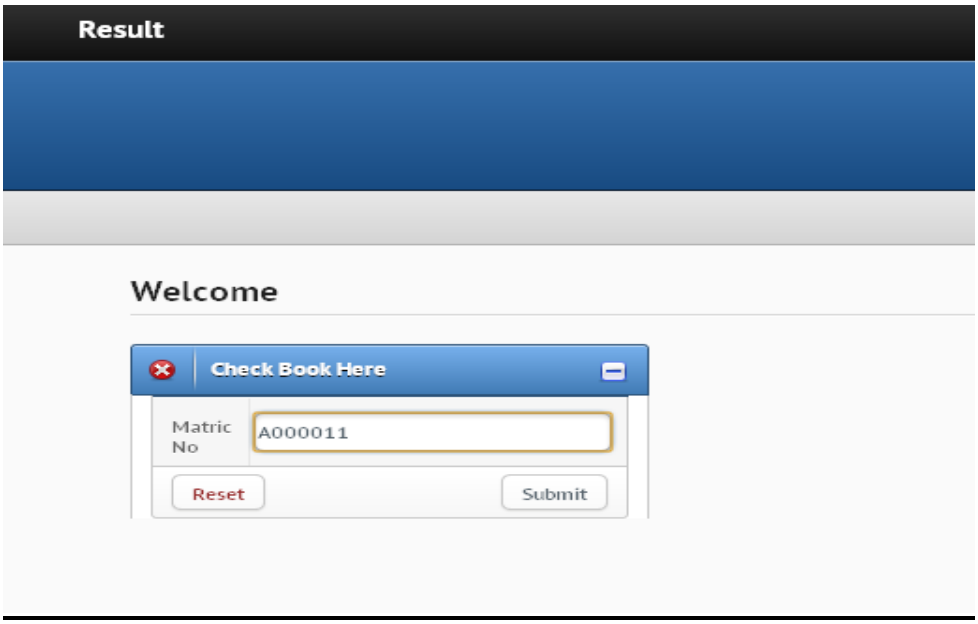

Figure 5.10: Checking Status Student Directly to ASIS for Borrowing Books Permission

5.2.4 Result of Validation

The validation of the prototypes also given to users (UUM Computer Centre's staff) to test (run) the prototypes and answer evaluation form given as attached in the Appendix 3. The evaluation result from the users is shown in Table 5.2.

Table 5.2: The Empirical Validation Result

	Prototype 1 (ASIS)	**Prototype 2 (LZS)**	**Prototype 3 (Library)**
Role / **Characteristics**	Service provider	Service consumer 1	Service consumer 2
Loose coupling	Achieved	Intermediate	Intermediate
Service based	Achieved	Achieved	Achieved
Reusable	Achieved	Achieved	Not Achieved
Real time data update	Achieved	Achieved	Achieved
Accessibility	Achieved	Achieved	Achieved
Reliability	Achieved	Intermediate	Intermediate
Security	Achieved	Intermediate	Intermediate

In accordance the result, overall the prototypes characteristics are achieved the goal to be a SOA based system. All those could be concluded achieved the quality attributes, which are interoperability, flexibility, and modularity in integrating heterogeneous IS.

5.3 Summary

The proposed conceptual model has been validated through experts review and empirical test techniques. The idea of evaluating the concept is clear, that despite being evaluated and validated by experts, the empirical results makes the findings stronger. In short, this study presents the proposed conceptual model for transferring a technology so that it could be a guide on how to embark the SOA concept successfully in heterogeneous IS. This is also important in bridging the gap between researchers and practitioners.

As a result, the SOA adoption has smoothen the SIS business process as well as helps the person in charge at the IS to use and manage the IS effectively and efficiently. On top of that, the problems related to poor interoperability system such as repeated tasks and difficulties in integrating among IS in the heterogeneous environment have been solved by applying SOA concept in SIS (refer to Section 5.2).

CHAPTER SIX
CONCLUSION

This chapter concludes a discussion about the SOA requirements to be incorporated into SIS, the proposed conceptual model and its validation. They are mapped with the objectives stated in Chapter 1. On top of that, this chapter also discusses the limitations in this study and recommendations for future enhancement. Also the contributions and implication of the study are highlighted.

6.1 Outcomes of the Research

As stated in Chapter 1, this study aims to achieve three objectives in solving the described problems. In accordance, the findings are discussed with regards to specific objectives.

6.1.1 Research Objective 1

The first objective is to identify the requirements of SOA for embarking into SIS. This objective is achieved by reviewing works in the previous studies. On top of that, it is supported by the interviews with the SOA experts. Eventually, all the data were analyzed, synthesized, and discussed at length in Chapter 2 and Chapter 4. In addition, the importance of SOA has also been reviewed for adopting into SIS. As the conclusion, the main requirements to implement the SOA-based system are XML has to use and a supported technology needed like WS technology where there will use SOAP or HTTP as the protocol transport to bring the data between service provider, registry and service consumer. While ESB is helpful when involve large distributed system integration.

6.1.2 Research Objective 2

The second objective is to construct a conceptual model of SIS based on SOA. This is also achieved by reviewing the existing SOA conceptual model in IS of university environment. As a consequent, this study developed a conceptual model for SIS requirement based on consensus from experts about the consolidated existing model

and modification for SIS. Eventually, this study obtained a conceptual model which has been verified by SOA experts (as discussed in Section 5.1). The important features or elements in the conceptual model are WSDL, SOAP, XML, Data Source, Registry, Service Provider and Consumer.

6.1.3 Research Objective 3

The third objective is to validate the SIS conceptual model based on SOA through empirical experiment. Three prototypes were involved with different types of databases and programming languages. The prototypes were successfully run and verified by two application consultants from IT industry and three stakeholders of the involved SIS in UUM. The application consultant verified that the features and functions built in the three prototypes have followed the appropriate model of SOA basic fundamental, where there are enough components as stated in the previous sections of 6.1.1 and 6.1.3. Through this empirical validation, it was proven that the conceptual model is useful in its context (explained in Chapter 5). Hence, it proves that the aim to enable the interoperability and flexibility integration among the heterogeneous IS is achieved and it could reduce the repeated tasks.

6.2 Limitations and Future Research

The study was limited to only some parts of SIS due to some constraint. The main limitations in this research are (1) lack of SOA expertise among the developers in the team, (2) time constraint, and (3) the needs of a high cost to implement the SOA concept in a large distributed SIS system which is built using various technologies in heterogeneous environment systems. As a consequent, this study was only able to empirically validate the conceptual model with a small sample of SIS.

In response to the limitations as described in the previous paragraph, this initiative could be improved in the future with some research direction as follows:

i) In this study, the proposed SoSIS conceptual model was evaluated through the experts review and empirically tested on a small SIS. Accordingly, it is highly to extend the work by evaluating SoSIS in the whole SIS. The evaluation can be

measured more rigorously when all the systems involved are able to successfully adopt the SOA concept.

ii) Only qualitative data are considered in this study. Hence, it is recommended that future works mix both qualitative and quantitative so that the findings are richer and more descriptive. Besides, they will be more convincing.

6.3 Research Contributions

The proposed conceptual model and related knowledge also can be leverage among IT professionals in higher learning institutes generally in Malaysia and specifically in UUM systems. The findings and results of this study benefits UUM in terms of providing a guideline for incorporating the SOA concept in its heterogeneous IS environment. As a result, the SOA adoption could have smoothened the SIS business process as well as helps the person in charge at the IS to use and manage the IS effectively and efficiently. On top of that, the problems related to poor interoperability system such as repeated tasks and difficulties in integrating among IS in the heterogeneous environment could have been solved (as described in Chapter 5).

Therefore, as a case study at UUM, this study has helped the Computer Centre by providing guidelines in creating usable and interoperable IS for the next generation. Besides, it provides end users with more usable IS and enhances the roles of the computer centre in providing good services to the university. In detail, major contributions of this study can be summarized as follows:

i. The requirements of the SOA-based IS have been successfully identified. This has been discussed in Chapter 4. The gathered information is mapped into the meaningful table and figure (refer Table 4.1 and Figure 4.1) that can help the other researchers and developers to provide the appropriate requirements in embarking SOA into their systems.
ii. The SoSIS conceptual model has been proposed and validated, then so it is considered accepted as a solution for SIS and other related IS in updating or easily integrating data across different IS environment so that it could be more flexible. It is an improvement for SIS because the current IS work with hard coupling seekers and is not able to interoperate in a heterogeneous environment.

iii. The conceptual model evaluation was conducted by involving the experts and empirical test the case study. The results of both techniques are accepted and thus it shows that the SoSIS conceptual model can be accepted as a guideline in embarking SOA into SIS and also other related IS.

6.4 Implication of the Study

The findings in this study could make-up an in-depth understanding about SOA through the conceptual model that has been incorporated into SIS of the heterogeneous systems. The conceptual model has been empirically validated when the prototypes run successfully as expected (as explained in Chapter 5). Therefore, the proposed conceptual model could be a guideline for embarking SOA concept into heterogeneous IS integration.

6.5 Summary of this Study

This study considers the incorporation of SOA concept into SIS, which is used in IS development that needs to update data in real time in the heterogeneous environment efficiently. It is important to avoid any latency time in updating any data since the repetition tasks occurred. Moreover, it will have redundant data because the difficulties of data integration among heterogeneous IS. Chapter 1 introduces the research problems and questions, objectives, scope, research framework and organization of this thesis. It is followed with a discussion on the background of the study which focuses on SOA and how the previous studies embarked in other systems in Chapter 2. The chapter also includes a discussion on several examples of the SOA conceptual model implemented into SIS. It has been revealed that most of the HLI have used the SOA concept in homogeneous environment. The previous studies do not mention how they interact or update the data among systems in a heterogeneous environment. On the top of that, the current problems in SIS at UUM were discussed and the importance to embark the SOA concept was also addressed. All requirements and information were analysed in detail. The results of this literature review had given useful information for developing the SIS conceptual model based on SOA.

In chapter 3, the techniques and methods used in this study are outlined. They are explained in a chronological order to achieve the objectives and solve the research problem. Further, Chapter 4 discusses the analysis and design works in creating the conceptual model based on SOA. The models used in previous works are combined, and adaptation is made to fit with the SIS requirements. In order to enhance the current model of SIS, services layer was added. The interoperability system is achieved with the services layer that consisting WS technology. The proposed model has been proven in producing better results than the current SIS conceptual model. The concept has been evaluated using expert reviews and empirical testing, as explained in Chapter 6.

In conclusion, this study has delivered its research objectives. The findings of the study could help universities and related organizations understanding insightful to embark SOA-based system especially involving heterogeneous IS with different environment by using the proposed conceptual model.

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APPENDIXIES

Appendix 1: Permission Letter for Experts Review

Nur Hidayat bt. Harun
School of Computing
College of Arts and Science
Universiti Utara Malaysia
06010 UUM Sintok

12th February 2012

TO WHOM IT MAY CONCERN

Prof./Dr./Sir/Madam,

PERMISSION TO CONDUCT INTERVIEW/ EVALUATION SESSION WITH SERVICE ORIENTED ARCHITECTURE (SOA) EXPERT

With reference as above matter.

I am Nur Hidayat bt. Harun, a MSc of IT (research) student at UUM (matric no. s802925), would like to conduct an expert review to evaluate and validate the conceptual model of my research as well as the prototype developed. My research is about SOA Adoption in Heterogeneous Student Information Systems (SIS).

The research involved a case study by investigating a modification on the existing SIS at UUM, based on service oriented architecture (SOA) concept. A conceptual model was constructed and three different prototypes were developed based on the conceptual model. An evaluation & validation on the prototype by SOA experts need to be conducted furthermore.

I would like to invite you as the expert or experienced person in SOA or web services to evaluate/validate and give some opinions/comments about my research project. Your kindness and cooperation is very much appreciated. All information gathered is for academic purpose only, and not to be commercialized.

Thanks you.

Your sincerely,
Hidayat

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Appendix 2: Questions for SOA Experts

Questionnaires

Please answer the questions given. Your time and effort are very much appreciated. The data gathered is only for the academic research purpose and your personal data is completely confidential.

Questions Part A: Expertise background

1. Did you ever get involved in any SOA development?

◉ Yes (If yes, please go to question 2-10)

○ No (Proceed to Part B)

2. What is the motivation behind the SOA development that you had been involved? (Answer can be more than one)

☐ Current IS development trend

☐ Faster to market

☐ Highly interoperability

☐ High performance of real time data updating

☐ Interested to gain experiences

☐ Cost benefits

☐ Time benefits

☐ Others (Please specify) _____

3. Could you please specify the project(s) that you involved?

Name of project(s)	Purpose(s)	Approach (e.g. Top down/ Middle out/ Bottom up)	In house / Outsource/ Individual	Project time frame (months/ years)	Project status (Successfully/ In progress/ Failed)

4. Is it critical to have a team of SOA expert in order to have a successful SOA project?

○ No

○ Yes

Please give reason for any answer

---

5. Form your experiences, what are the most important requirements at the initial stage of SOA development? Answer can be more than one.

- ☐ Disccusion with all stakeholders
- ☐ Business requirement
- ☐ Architecture design
- ☐ Programmers team
- ☐ Decision of software/tools to be used either open source or liciense product
- ☐ Others (Please specify)

_____

6. What are the problems encountered at the initial stage of the development? Answer can be more than one.

- ☐ Difficut to get SOA consultant/expert
- ☐ No executive support
- ☑ Improper planning due to ad hoc
- ☐ Others (Please specify)

_____

Questions Part B: SOA Knowledge

1. From your experience and knowledge, what are the basic elements required to produce a SOA based system? You can check more than one answers listed below.

☐ Service provider	☐ SOAP	☐ Internet connection
☐ Service consumer	☐ WSDL	☐ Others if any (please specify)
☐ XML	☐ HTTP/FTP/SMTP	_____

2. In general, what are the critical success factors for SOA development?

- ○ Web service technology
- ○ Software/tools

- Architecture system
- Other (Please specify)

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3. In your opinion, what is the most appropriate method to validate conceptual model of SOA based?

   - Planning Method
   - Expert Review
   - Applied in Real Situation
   - Family Architecture Assessment Method (FAAM)
   - Architecture Level Modifiability Analysis (ALMA)
   - Other (Please specify)

   _____

Questions Part C: Regarding to the prototypes

You needs to review the prototypes (refer attachment files) and answer the questions given.

1. Refer to the appendix A.
   Please rate your level of agreement with the prototype of ASIS as services provider.
   - Very satisfied
   - Somewhat satisfied
   - Neither satisfied nor dissatisfied
   - Somewhat dissatisfied
   - Very dissatisfied

2. Refer to appendix B
   Please rate your level of agreement with the prototype of LZS as services consumer.

- Very satisfied
- Somewhat satisfied
- Neither satisfied nor dissatisfied
- Somewhat dissatisfied
- Very dissatisfied

3. Refer to appendix C
Please rate your level of agreement with the prototype of Library system as services consumer.
   - Very satisfied
   - Somewhat satisfied
   - Neither satisfied nor dissatisfied
   - Somewhat dissatisfied
   - Very dissatisfied

4. Based upon overall these prototypes, please rate your satisfaction in the following achievement:

Characteristics/ Benefits	**Very satisfied**	**Somewhat satisfied**	**Neither satisfied nor dissatisfied**	**Somewhat dissatisfied**	**Very dissatisfied**
Interoperability					
Smoothen the heterogeneous IS operational					
Reducing repeated operational tasks					
Reduced maintenance cost					
Automated data update on real time					
Easy to use					
User friendly					

5. Do you agree using SOA solution for heterogeneous IS integration for in this case study?

- Yes
- No (Please give reason/suggestion)

_____

_____

6.For overall about all these prototypes, please rate your satisfaction.

- Very satisfied
- Somewhat satisfied
- Neither satisfied nor dissatisfied
- Somewhat dissatisfied
- Very dissatisfied

7.Do you have any additional comments about your experience or suggestions on how these prototypes could be improved?

_____

Thank you very much for your time and valuable input!

Appendix 3: Users Evaluation Form

Please fill in the blank to evaluate the prototypes. You can use ranking as the following.
1-Not Achieved
2-Quite Not Achieved
3-Intermediate
4-Quite Achieved
5-Achieved

	Prototype 1 (ASIS)	**Prototype 2 (LZS)**	**Prototype 3 (Library)**
Role / **Characteristics**			
Loose coupling			
Service based			
Reusable			
Real time data updated			
Accessibility			
Reliability			
Security			