SERVICE ORIENTED ARCHITECTURE (SOA) IMPLEMENTATION FRAMEWORK FOR HETEROGENEOUS INFORMATION SYSTEMS INTEGRATION

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Abstrak

Kepelbagaian sistem maklumat (IS) menyukarkan untuk menyatukan data secara automatik dalam persekitaran IS yang berlainan. Keadaan ini telah menyebabkan kos operasi and penyelenggaraan meningkat dan juga pembaziran ruang simpanan data, yang berpunca daripada data yang bertindan. Semenjak kemunculan aliran terkini pembangunan IS, iaitu Senibina Berasaskan Perkhidmatan (SOA), ramai pengkaji telah mencadangkan pelbagai model konseptual dan rangka kerja SOA. Objektif utama usaha ini adalah untuk menjadi panduan untuk mengaplikasi SOA dengan jayanya. Di Malaysia, banyak institut pengajian tinggi telah mengambil satu inisiatif untuk melaksanakan sistem berasaskan SOA untuk meningkatkan kualiti persembahan IS. Walau bagaimanapun, kebanyakan rangka kerja SOA yang sedia ada masih kekurangan dari segi reka bentuk yang bagus untuk menyokong penyatuan kepelbagaian IS. Dalam mengisi kekurangan ini, kajian ini dijalankan untuk mencari ruang bagi menambahbaik rangka kerja pelaksanaan SOA yang sedia ada dalam integrasi kepelbagaian IS. Satu kombinasi kepelbagaian rangka kerja yang sedia ada dan persetujuan dari para pakar telah menghasilkan satu rangka kerja baru SOA. Kaedah kajian kes di sebuah universiti awam Malaysia telah diaplikasikan untuk menguji dan mengesahkan rangka kerja tersebut dengan menjalankan ekperimen prototaip dengan memfokuskan kepada beberapa sistem maklumat pelajar. Penilaian dari para pengguna menunjukkan rangka kerja yang diusulkan itu telah memenuhi beberapa kriteria SOA seperti berasaskan perkhidmatan, kemaskini data dalam masa yang nyata serta kebolehan capaian dan dibuktikan dengan jayanya melalui ekperimen prototaip. Dengan penemuan dan hasil dari kajian ini, satu penambahbaikan rangka kerja pelaksanaan SOA telah dipenuhi dengan memfokuskan di dalam integrasi kepelbagaian IS. Ini adalah satu sumbangan baru kepada badan pengetahuan dalam bidang SOA dalam aspek penyatuan kepelbagaian IS di universiti awam Malaysia.

Kata kunci: Senibina Berasaskan Perkhidmatan, Penyatuan Kepelbagaian, Sistem makluma.

Abstract

Heterogeneous information systems (IS) creates difficulties to automatically integrate data in different IS environment. These situations have increased operating and maintenance costs as well as wasteful data storage, which is caused by data redundancy. Since the emerging of Service Oriented Architecture (SOA), the latest trend in IS development, many researchers have proposed various SOA conceptual models and frameworks. The main objective behind these efforts was to provide a guideline for a successful SOA adoption. In Malaysia, higher learning institutions have taken some initiatives to implement SOA-based systems to improve the quality of IS performance. However, most of the existing SOA frameworks available are still lacking of good design to support an integration of heterogeneous IS. In order to fill this gap, this study was conducted to seek for an opportunity to enhance the existing SOA implementation frameworks of heterogeneous IS integration. A consolidation of the existing related frameworks and consensus from experts yield a new SOA framework. A case study approach in a Malaysia public university was applied to test and validate the framework by conducted prototyping experiments with the focus on several student information systems. The evaluation from the users shows that the proposed framework has met SOA criteria like service based, data update in real time and accessibility. This finding has been proven with successful prototype experiments. With the findings and results of this study, an enhancement of SOA implementation framework was fulfilled by focusing on integrating heterogeneous IS. This is a new contribution SOA domain in the context of heterogeneous IS integration in Malaysia public universities.

Keywords: Service Oriented Architecture, Heterogeneous integration, Information systems.

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List of Abbreviations

ADX	Advance Data Exchange
ASIS	Academic and Student Information System
CORBA	Common Object Request Broker
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
SoSIS	Services oriented Student Information Systems
OS	Operating System
WSDL	Web Services Description Language
WS	Web Service
XML	eXtended Markup Language

CHAPTER ONE
INTRODUCTION

Service-oriented architecture (SOA) approach was emerging as a popular design concept of an information system (IS) development in recent years. SOA is an architectural style that is based on service concept (Erl, 2009). Many people have begun to talk about SOA and its advantages in contributing to agile IS development and efficient management on a number of articles have been published a year after year (Mohammed Al-Khannaq, 2009; Perniu, 2010; Yihui, 2011; Börner & Goeken, 2012). However, since SOA is still new for most organizations, many stakeholders of the organizations are concerned on appropriate way to implement SOA approach for their organizations' IS (Balk, 2008; Li, Chen, Zhu, & Chung, 2010; Ma & Liu, 2013). To overcome this shortcoming, the related researchers such as Roach, Low and D'Ambra (2008), Alghafri et al. (2009), Jabr and Al-omari (2010), and Razavian and Lago (2010) had published their conceptual models and frameworks as a guide to help peoples understand SOA adoption and implementation. Nevertheless,, there are still lack of a good framework design for SOA implementation (Moody, 2005; Pansa, Walter, Abeck, & Scheibenberger, 2010; Aydin & Yalcinkaya, 2011). This issue also was suggested to be solved by Pansa, Walter, Abeck, and Scheibenberger (2010) and Trkman, Kova, and Kardeljeva (2011) that claimed a framework of SOA implementation should be presented in details and clearly.

Previous studies (Lupu, Bologa, Sabau, & Muntean, 2008; Pasatcha & Sunat, 2008; MohammedAl-Khannaq, 2009) found that in education domain, many higher learning institutions (HLI) has seen an increased numbers of stakeholders, who are interested in exploring and implementing SOA into their organizations' IS to leverage SOA

benefits such as flexibility and interoperability (Gabhart & Bhattacharya, 2008; Asuncion, Iacob, & Sinderen, 2010; Welke, Hirschheim, & Schwarz, 2011; Börner et al., 2012). This attraction to adopt SOA among HLI stakeholders had also been influenced by IS in HLI today, that were found to be complex, composed of heterogeneous IS, and integrated with hard coupled point-to-point connections to meet changes of business demands (Josuttis, 2007; Yu et al., 2011).

In Malaysia, Mohammed Al-Khannaq (2009) argued that not many studies have been published, contributing to the knowledge on SOA and its implementation in HLI. Hence, this study is proposed to enhance the existing SOA frameworks within Malaysian HLI's context by employing a case study approach in a Malaysia's public university to conduct prototyping experiments in order to validate the proposed SOA implementation framework of heterogeneous IS integration. The selected university represents an organization with heterogeneous IS that consists of different types of data sources and programming languages, which is isolated, making it hard to integrate data in real time. These situations lead to increased operation and maintenance costs, wasted data storage and increased use of data sources.

1.1 Problem Background

Issues as stated in the above section of heterogeneous IS in a distributed system have to be automated data integration with real time updates. There are many existing data integration approaches (Roach, Low, & D'Ambra, 2008; Hribernik, Kramer, Hans, & Thoben, 2011), however some weaknesses such as tightly coupling needs to be overcome (Chan, Choo, Lau, & Yeoh, 2012). For example, data warehouse approach as the most popular integration approach before has poor interoperability and difficult

to update data among heterogeneous IS in real time (Hribernik et al., 2009). This approach uses a centralized data source to collect and store all required data from other sources to be used later by another IS or data sources. Obviously, the data updating will have a latency time since it is not directly updates into another sources.

In the past several years, SOA has emerged as an IS development approach of architectural style and was proven to be a better solution for heterogeneous IS integration rather than other integration approaches (Paganelli, Parlanti, & Giuli, 2010) since SOA can serve real time data updates and has high interoperability. SOA basic paradigm, which involves services registry, provider and consumer as well as web services concept, gives a loose coupling as a fundamental concept of SOA (Josuttis, 2007; Mabrouk, 2008). Therefore, it could reduce dependencies of human intervention for heterogeneous IS integration (Stal, 2006; Perko, 2008). Besides, loose coupling of SOA characteristics enables higher interoperability (Josuttis, 2007) that can also make a real time data updates. This attribute is very influential in solving integration problem especially for the heterogeneous IS. Thus, studies were conducted to further investigate of how to implement the SOA approach into heterogeneous IS by producing a proper implementation framework to leverage the benefits further (Kim & Yun, 2006, Sept.; Mircea, 2012).

1.2 Problem Statement

Many articles have been published about SOA (e.g; Perniu, 2010 Mason & Ellis, 2010; J. Wang, 2013; F. Q. Wang, Qi, & Liu, 2013). However, most of them highlighted more on the theoretical and implementation factors of SOA despite of how to implement SOA with a guide of a good framework. There is only several previous studies discussed on SOA implementation guide by proposing SOA

conceptual models or frameworks as proposed by Allan (2005), Pasatcha and Sunat (2008), Lupu, Bologa, Sabau and Muntean (2008), Yen and Hsu (2008, Sept.), Alkhanak and Mokhtar (2009), Jabr and Al-omari (2010), Yihui (2011), and Ying-pei and Ting-ting (2011). Specifically for heterogeneous IS integration, there are a limited number of studies (Balk, 2008; Offermann & Bub, 2009; Alkhanak & Mokhtar, 2009; Selamat & Kharusi, 2009; Ying-pei & Ting-ting, 2011; Yihui, 2011) on SOA implementation frameworks. However, their frameworks are not good design since they are lack of information of how the integration among heterogeneous IS occurred., The latest study by Trkman, Kovocic, and Popovic (2011) have suggested to tackle this problem by providing more detailed guidance to assure successful implementation of SOA. Therefore, in this regard, the study is conducted to propose an enhanced SOA implementation framework for IS heterogeneous integration.

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 improve the existing SOA implementation framework for heterogeneous IS integration?" Additionally, the following sub-questions have been answered in the next section of research objectives.

i. What are the important elements that influence SOA implementation succeeding in heterogeneous IS integration?
ii. How to produce a good quality of SOA implementation framework for heterogeneous IS integration?
iii. How to measure the effectiveness of the proposed framework?

1.4 Research Objectives

The main objective of this study is to enhance an SOA implementation framework of heterogeneous IS integration with prototypes experiments. It is necessary to solve the problems discussed in detail 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 important elements for SOA implementation succeeding in heterogeneous IS integration.
ii. To construct an SOA implementation framework of consolidation existing frameworks.
iii. To validate the proposed SOA framework.

1.5 Research Scope

In providing a validation for the proposed SOA implementation framework of the heterogeneous IS integration, the study was supposed to undertake the involvement of a distributed system. However, it would take a longer time and impossible to be accomplished within a limited expert team, budget, and time of this study as it involves many IS with a big size of data. Thus, to answer the research questions addressed in Section 1.3, which is specifically related to HLI, a case study approach is considered appropriate and sufficient. Also, since the IS is involved in the distributed system, it is good to develop the SOA-based IS into a small scope as a starting point. According to Roboostoff (2007), it is better to start a big project with a smaller 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. Therefore, in this study, three

main IS of student information systems in the case study of a university were chosen to conduct prototype experiments. They are made up of heterogeneous IS environment which are Academic and Student Information System (ASIS), Learning Zone System (LZS), and Library System, in which they use different types of data sources and programming languages (Figure 1.1).

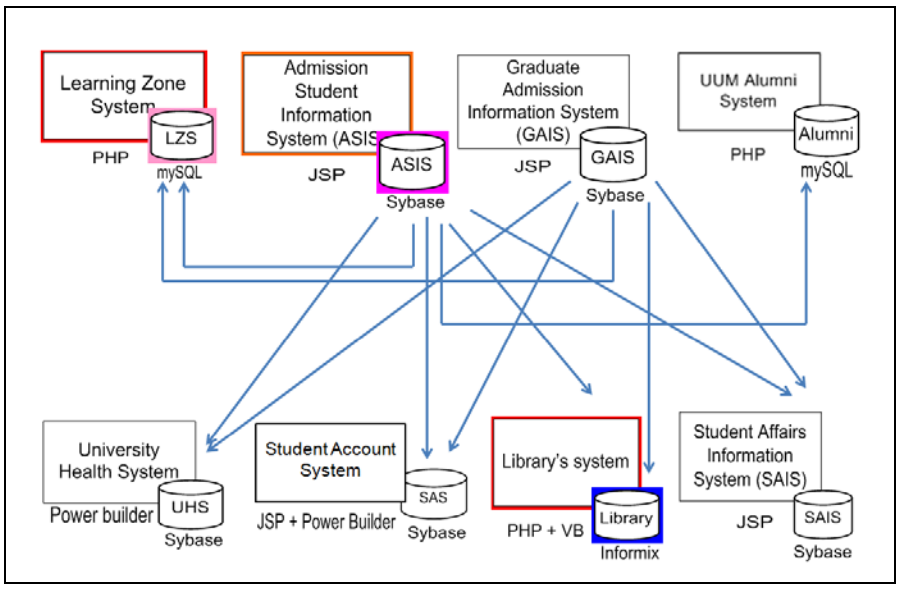

Figure 1.1. The heterogeneous SIS

1.6 Research Framework

This study aims to apply empirical validation of prototype experiments for the proposed SOA implementation framework in solving the integrated communication among heterogeneous IS. In accomplishing this, various methods were undertaken. Table 1.1 exhibits a summary of the research methods with their expected outcomes and its contribution.

Table 1.1

Research Framework

Title : SOA IMPLEMENTATION FRAMEWORK FOR HETEROGENEOUS DATA SOURCES INTEGRATION: A CASE STUDY IN A MALAYSIA PUBLIC UNIVERSITY							
Research Problem (RP)	**Main Research Question (RQ)**	**Sub-Questions (SQ)**	**Main Research Objective (RO)**	**Sub objectives (SO)**	**Research Methods (RM)**	**Expected Outcomes (EO)**	**Expected Contribution (EC)**
Current IS in Malaysia HLI are mostly not highly interoperability among heterogeneous IS, which is not able to update data in real time. The SOA approach is found to be a good solution. However, the existing SOA implementation conceptual models and frameworks are still lack of a good design to be an implementation guide especially for integrating heterogeneous IS.	How to improve the existing SOA implementation framework for heterogeneous IS integration?	SQ1: What are the important elements that influence SOA implementation succeeding in heterogeneous IS integration?	To propose an SOA implementation framework of heterogeneous IS integration with prototypes experiments.	SO1: To identify the important elements for SOA implementation succeeding in heterogeneous IS integration.	Literature review -Documents sampling/analysis - Do a content analysis for the previous SOA frameworks and conceptual models. Interviews -SOA Experts -Stakeholders	The important elements and requirements of SOA implementation succeeding	A validated SOA implementation framework for the heterogeneous IS integration
		SQ2: How to produce a good quality of SOA implementation framework for heterogeneous IS integration?		SO2: To construct an SOA implementation framework of consolidation existing frameworks.	-Get the consensus from experts review for the consolidation existing SOA frameworks	A verified SOA implementation framework that incorporates into the consolidated existing SOA frameworks	
		SQ3: How to measure the effectiveness of the proposed framework?		SO3: To validate the proposed SOA framework.	-Prototypes development using SOA Method (SOAM) - Users' evaluation (experts & stakeholders)	Results of the users' evaluation.	

1.7 Significance of the Study

This research is essential in the contribution to the body of knowledge for exploring in depth on how to implement SOA approach into heterogeneous IS integration. As the result, it proposes an SOA implementation framework for current requirements of business processes and IT, especially for IS to be interoperable IS with heterogeneous environment in the context of HLI in Malaysia.

1.8 Research Contribution

By proposing the framework of SOA-based implementation with prototypes experiments, it could support strong result to ensure the proposed framework is effective and help other researchers know in depth on how to implement SOA approach for heterogeneous IS integration. Further, the proposed framework could also contribute to the stakeholders in the HLI domain in Malaysia context as a guide to implement SOA.

1.9 Organization of the Report

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

Chapter 2 reviews the issues of heterogeneous IS in HLI and existing IS integration approaches, literatures related to SOA and its characteristics for real time heterogeneous IS integration. On top of that, it also reviews the related existing SOA

conceptual models and frameworks. Besides, it identifies the requirements of succeeding SOA implementation factors as well as the validation techniques used through the related previous works

In Chapter 3, description of the research design is addressed. The works are divided into problem definition, suggestion, framework construction, validation and evaluation, and final report phase. Additionally, the appropriate IS development methodology is also discussed at length in the validation phase.

Next, Chapter 4 discusses the data analysis and its outcomes using content analysis technique. Several related previous studies were compared and consolidated for heterogeneous IS integration. The gathered data were used to enhance and construct an implementation framework based on SOA approach incorporated within it.

Then, Chapter 5 follows by evaluating and validating the SOA implementation framework. On top of that, the consensus experts for proposed framework, prototypes testing and users' evaluation are also addressed. Next, the results and findings are discussed in details in the Chapter 6. This is followed with an overall summary in Chapter 6.

1.10 Summary

As conclusion, this chapter formulates the problem statement, research questions, research objectives, its focused scope, significance and contribution of the study. There is also a brief outline of the reporting organization. All the attempts made 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

This chapter discusses the current and previous works related to this study specifically about heterogeneous IS integration that used SOA approach. In the support of accomplishing the study objectives included to propose a framework of SOA implementation in HLI for heterogeneous IS integration, some related literatures are reviewed. They are discussed at length in the following separated sub-sections below.

2.1 Heterogeneous Information Systems

The different information systems (IS) environments so called as heterogeneous IS (Liu, Zeng, Huang, & Xu, 2010) consists of various types of data sources, programming languages, servers, operating systems (OS) and technologies used (Fengguang, Xie & Liqun (2009). Nowadays, in an organization there will be at least one IS for data recording or information display of their business. There are IS in most of domains or sectors such as in health, telecommunication, education, government and factory sector, which are having their own IS to support their business processes. Usually, an organization will be interacted with other organizations via IS networking either using internet online or offline. Hessami and Karcanias (2011) argue that most of the IS communication processes are difficult to implement effectively with business level strategies since the close integration of business, operational and design issues was not taken in systematic way.

For example in this study's scope of education sector, in Higher Learning Institutes (HLI) are usually composed of several business processes with various IS supported (Jabr & Al-omari, 2010). The IS mostly have a number of modules to form a large

distributed system in supporting their operation data management in the HLI across various departments, schools, and centres (Lupu et al., 2008). These majors IS normally include student information systems for undergraduate and postgraduate matters, learning and teaching management systems, examination system, library system, and graduation system. Each of the IS plays different roles in supporting their business processes that often referred to a silo, which tends to be independently managed and isolated from one another (Josuttis, 2007).

Despite of that, conventionally IS development approaches will be built on closed architecture and stove-piped design (Diebner & Herrera, 2013) such as different types of data sources, which makes those IS are decentralized and isolated from its data residing at different data sources. Moreover, from observations made by Klink, Oberweis, Ried, and Trunko (2006), most IS in HLI are developed separately using different platforms, programming languages and technologies. This phenomena supports findings by Ying-pei and Ting-ting (2011),who found out that the existing IS in HLI were mostly developed separately in different locations with heterogeneous environments of data sources and programming languages types. This situation arose some issues in IS management.

2.1.1 Issues of Heterogeneous IS in HLI

Most issues appeared in organizations is challenging to the IS management. Difficult task occurred when there are various technologies used and have to align with business demands from time to time. Even in an IS, there have their own difficulties to make changes if its business process changed or do modification as users' request. All these because the IS architecture itself is tightly coupled. On the contrary, it will cause hard integration between heterogeneous IS environment such as different types

of data sources, programming language and platform of server used (Fengguang, Xie & Liqun (2009).

This is also similar case in HLI, where most of them having heterogeneous IS to sustain their business processes (Selamat & Kharusi, 2009).This is because the IS architecture is tight coupled and cannot be flexible to do any data exchange rapidly to fulfil the business demands. Besides, heterogeneous types of data sources caused difficulties to combine and integrate data for providing users with a unified view of the data (Halevy, 2001; Nikayan, 2009). Usually, a manual selection will be done and it is unable concurrently update the data on real time. Then, repeated operational tasks will be occurred. Therefore, data integration becomes a major challenge due to IS architecture design of the heterogeneous IS environment, and thus could threaten HLI's business processes and operation since changes either from a business perspective or technical perspective is vital to deal with IS changes as well (Elfatatry, 2007).

2.1.2 Case Study in a Malaysia HLI

Until recently, most common functions of IS in HLI supported the maintenance of personal and study information relating to handling inquiries from prospective students; handling the admissions 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. This demand is seen in Universiti Utara Malaysia (UUM), the 6th public university in Malaysia that is supported by distributed systems with minimum features of interoperability.

These systems operate in heterogeneous IS environments involving different types of data sources, platforms, servers, operating systems (OS) and programming or scripting languages. Supporting the e-learning facilities at UUM, Learning Zone System (LZS) for instance, uses MySQL server database, Linux Solaris OS, Apache Web server and PHP programming while ASIS, which supports the academic matters, uses Sybase database, Linux OS, Enterprise Architecture (EA) server and Java script programming (JSP). Since both systems are using different data sources, scripting languages and servers, there exist some difficulties in IS integration between them. Both of these IS, at certain functions, also request and provide data to other IS in the university. In illustrating the complexities in a greater focus, Figure 2.1 shows a scenario of the working relationship among different IS in UUM, which consists of ASIS, Graduate Information System (GAIS), the Library System, University Health System, UUM Alumni System, LZS, and College or Student Residential Hall System that are separated in heterogeneous IS environment in different locations within UUM (Zainun Ngah, personal communication, May 13, 2009).

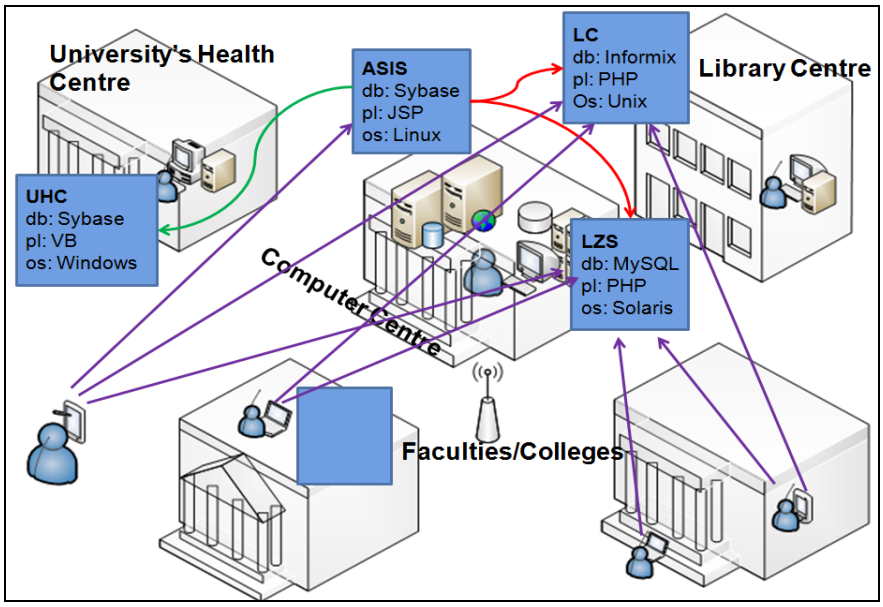

Figure 2.1. The Scenario of the IS Communication in UUM

The heterogeneous IS lead to integration challenges for users, especially to persons in charge of each IS who are required to update the data frequently. Without automated integration, similar data must be updated manually in various IS. This is a repetitious task and a waste of resources. This scenario can be seen in the case of the admission of a new student. In the beginning, a student must fill in a personal information form in which the details are the manually typed into the admission module in ASIS by the person in charge. After that, the identification process is repeated for the student residence hall system. Furthermore, some identifying information also is typed manually for the library system, which uses a different data source and programming language. With reference to this scenario, this researcher argues that various IS (in this scenario, the student residence hall and the library system) are supposed to extract certain information automatically from the main IS (in this scenario is ASIS) so that could make the IS management more efficiency. Therefore, a good and effective IS integration approach is needed to support the business processes and to be more interoperable IS especially for automated heterogeneous IS integration.

2.2 Heterogeneous IS Integration Approaches

The concept of integrating IS is certainly not new and most of organizations in the world including HLI in Malaysia have their own method for accomplishing the integration. There are three types of common IS or application integration level; at presentation, business logic and data layer, where all of these can be implemented by using human resources involvement, file transfer, direct data access, program calls, screen scraping, message communication protocol (eg. TCP/IP, HTTP, FTP), extracting, transforming and loading (ETL) and the latest is web services (WS). The focus in this study however is about data integration or also known as schema

integration, which means integrating data sources. Below is the discussion of some existing data integration approaches for heterogeneous IS.

2.2.1 Traditional Approach

A common approach that was used in data integration is by using manual selection so called on-demand approach. The person in charge of the data source management will find appropriate set of data sources to answer the query from another data source of IS by generate commands for the data source. The obtained results will be translated and merged the data into the required data source of another IS. However, the method used mostly is often challenging; inflexible, costly and frequently requiring manual intervention (Hasselbring, 2000; Linger et al., 2012; Baghdadi & Al-Bulushi, 2013). This approach is not relevance for real time data integration since it involves heterogeneous IS environment such as different types of data sources and programming language. Hence, the traditional approach of data integration is more for homogeneous IS environment such as process-oriented and data-oriented approach (Nikayin, 2009) that uses programming languages of SQL query to view data from another system. Meanwhile, object-oriented approach was widely used in the 90s (Nikayin, 2009) where the data is defined as an object in a class. Then, emerged component-based approach and today in the 21st century, there are a number of modern approaches known as service-oriented approach emerged (Nikayin, 2009). Different data integration approaches have a different method and impact. Table 2.1 summarizes the strengths and weaknesses of each data integration approach.

Table 2.1

The strengths and weaknesses of integration approaches

Data integration approaches	Strengths	Weaknesses
Process-oriented approach	Considering the architecture of computer and networks (Nikayin, 2009)	-Not to be easily extended when there are changes in the type of data in the systems (Slepi, 2010) -Not adequate for providing the business environmental requirements (Nikayin, 2009)
Data-oriented approach	Considering the architecture of computer and networks (Nikayin, 2009)	-Not adequate for providing the business environmental requirements (Nikayin, 2009) -Difficult to develop a system by primarily focusing only on one aspect (Slepi, 2010)
Object-oriented approach	-Decomposes problems into objects and then enable developers to focus on the entity in the system that actually does processes & carries data (Slepi, 2010), -Considering the architecture of computer and networks (Nikayin, 2009) -Class of objects can be reused (Boertien et al., 2002)	-It is complicated to integrate heterogeneous IS (Nikayin, 2009) -Not adequate for providing the business environmental requirements (Nikayin, 2009) -It cannot be reused (Boertien et al.,2002) -Changes of internal details do not spread into the system architecture (Elfatatry, 2007)
Component-based approach	-Involved from object oriented to emphasize reuses, fast adaptability to changes (Boertien et al.,2002) -Parts of a software system can be developed separately and then added to the system later (bound) (Elfatatry, 2007).	Approach to binding: main component-based software always assumes early binding upon components; that is, the caller unit knows exactly which component to contact before runtime (Elfatatry, 2007)
Service-oriented approach (modern approach)	-Binding approach more flexible: the binding is deferred to runtime, enabling the change of the source of provision each time runtime (Elfatatry, 2007) -Accommodates the change in the quality of the requirements over time (Bennett et al., 2000; Budgen et al., 2004) -Easier integration of heterosgeneous IS (Nikayin, 2009; Sim & Wang, 2005) -Not changing other components during modification for new types of requirements (Schelp & Winter, 2007) -Consider not only architecture of computer and networks but also the business environment (Nikayin, 2009; Komoda, 2006)	Need more cost to start in a distributed system and will take a long time to achieve overall services functional

2.2.2 Modern Approaches

Revolution of data integration approach occurred as a response to support insufficiency exists in the previous approaches for heterogeneous IS environment. The review of previous heterogeneous data integration approaches had been discussed before by Fengguang, Xie and Liqun (2009) about Federated Database (FDB), Data Warehouse and Wrapper-Mediator and found that an enhancement should be added so that it could increase effectively of operation on the data sources. The study then proposed a framework based on XML to improve the effectiveness by enabled automatically XML schema integration, which is using XQuery. However, this framework is only benefit for developer or users that know the query language. For end users of non-programming person, this method is difficult to use.

Besides, loose coupling components of end-to-end points connection among heterogeneous IS is necessary to be flexible integration. Therefore, open-standard and open-interface architecture were introduced to solve the IS integration (Diebner & Herrera, 2013) and overcome all the weaknesses of the previous approaches. The next sub-sections will explain more in details for the tightly and loosely coupled.

2.2.2.1 Loosely vs Tightly Coupled

As known as one of the most popular data integration approach is data warehouse that provides quick efficient for heterogeneous IS integration. Data warehouse uses a centralized data source to collect all relevant data from other sources and store into it to be used by another IS or required another data sources. This approach is quite efficient in responding data request in a short period as compared to the traditional approach. Figure 2.2 depicts a diagram of data warehouse integration approach. It

uses ETL process to get data from various data sources into a centralised data source as its repository.

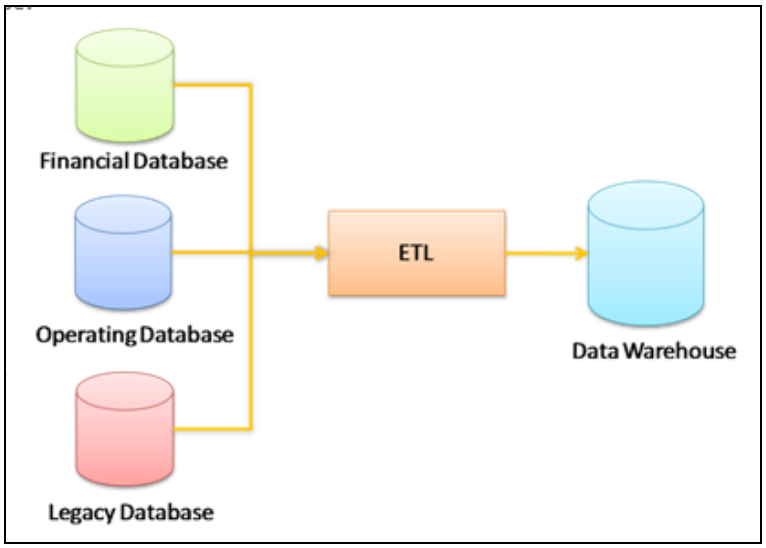

Figure 2.2. Data Warehouse Integration Approach

However, there is a weakness of latency time during data updating activity, whereby the gathered data from another data source of IS need to be placed in a local data source before to be used or requested from another IS to update the required data into another data source. Besides, the data warehouse, operational data store (ODS) and Federated Database System approach (refer Figure 2.3) are categorized into tightly coupled of data integration approach characteristics (Hribernik et al., 2011; Zhang & Shao, 2011; Chan, Choo, Lau, & Yeoh, 2012), which is difficult to be on real time data updated.

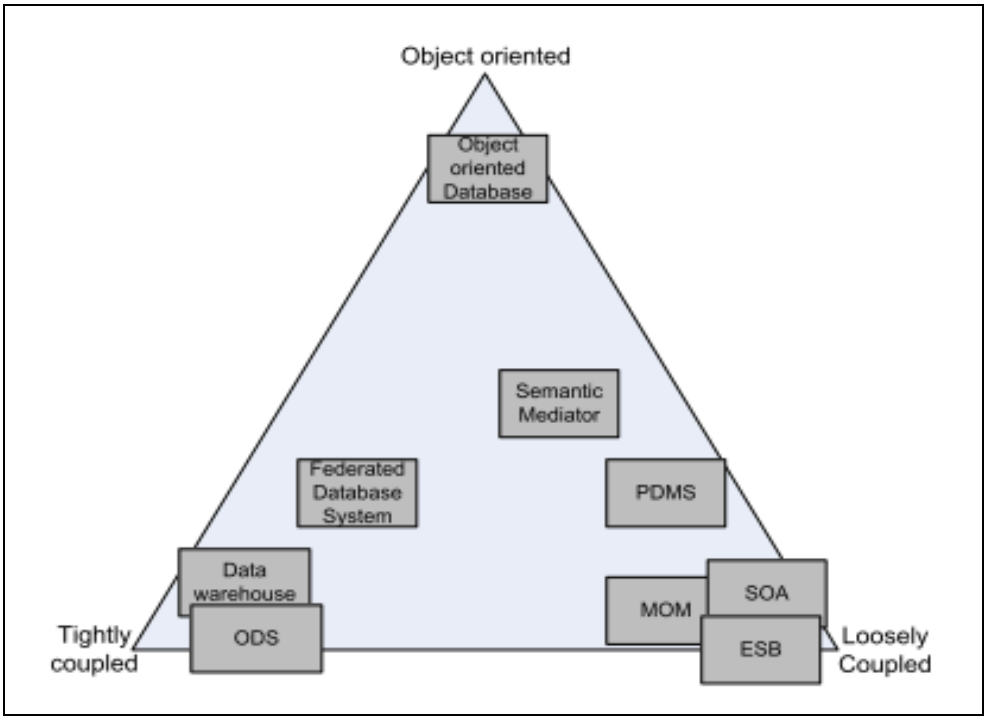

Figure 2.3. Classification of Data Integration Approach Characteristic (Adopted from Hribernik et al. (2009)

Integration of IS should help enterprises to automate their business activities, enhance and improve the business processes and operations with other providers (Nikayin, 2009). A good integration approach will offer efficiency and productivity in managing the IS. Therefore, it is vital to have a loosely coupled architecture like ESB, MOM and SOA approach suited with services that can be used within multiple heterogeneous IS from several business domains to enable interoperability and flexibility system. Besides, the most crucial characteristics of designing architecture for heterogeneous IS integration is reusability, scalability and agility (Lyytinen et al., 2008). Hence, SOA is one of the recommended approach to solve problems of conventional modelling methods that appears to be service orientation (Aydin & Yalçınkaya, 2011), which is open standard architecture. The latest approach of service-oriented approach; SOA recently become popular among IS developers as it is

a good solution for heterogeneous IS today. In accordance, the SOA approach is further discussed in the following subsections.

2.2.3 Service Oriented Architecture (SOA)

SOA is an architectural style that is based on service concept. It forms the basic SOA principles including reuse, loosely-coupled, encapsulation, interface/appearance strict definition and dynamic nature (Bo & Kaihu, 2010; OASIS, 2006). 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. Meanwhile, Bieberstein et al. (2005), OASIS (2006), and Bo and Kaihu (2010) defined SOA as a framework for integrating heterogeneous data based on 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 it is a bridge between business and IT gap (Erl, 2008). 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 the service provider for the benefits of service client. On top of that, Papazoglou and Georgakopoulos (2003) state that, services are self-describing, open components that sustain rapid and low-cost composition of distributed applications. Architecture of SOA brings a meaning of combination of models that describe a structure of subsystem's components, which comprises of components, the externally visible properties of those components and the relationships among them (Bass, Clements & Kazman, 2003; Papazoglou & Georgakopoulos, 2003). SOA has emerged into the business world as a highly prominent architectural style (Viering, Legner, &

Ahlemann, 2009). Therefore, the architecture of a system could be defined as a model that describes the structure of an IS in terms of computational components, the relationships among components, and constraints for assembling the components.

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). These 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 2.4. 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 service providers to service consumers or requestors (Mahmood, 2009). The commonly used standard service registry is Universal Description Discovery and Integration (UDDI), and Electronic Business uses 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 service and binds to service endpoint.

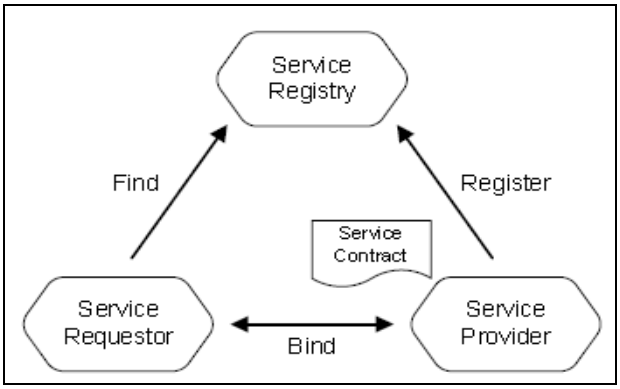

Figure 2.4. SOA Theory (Adopted from Michlmayr et al., 2007)

These basic paradigms will give a loose coupling as a fundamental concept of SOA (Josuttis, 2007; Mabrouk, 2008). Therefore, it could reduce dependencies between heterogeneous IS (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 influential in solving the systems integration problem especially for the heterogeneous systems. The acceptance of SOA as an approach to integrate heterogeneous IS and services is because its characteristics; loose coupled, scalable, interoperable, componentized and modular (Erl, 2008). The next section discusses more about SOA incorporating with the stated characteristics in the above.

2.2.3.1 SOA Characteristics

The most popular technology used to support SOA-based system for heterogeneous IS is the web services (WS) (Alwi A., 2011). This is due to the fact that WS not bounded to any programming languages and OS as it used XML language, which is can be a translator among different programming languages. In practice, most IT practitioners do not follow the SOA triangle in Figure 2.4. Instead, only two elements are in focus; service providers and service requestors as shown in Figure 2.5. 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 the service requestor and provider is limited to a certain system that has been defined by the system provider (Leymann, Roller, & Schmidt, 2010).

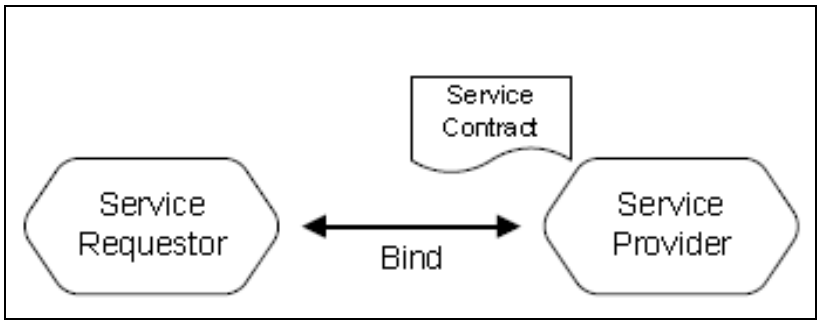

Figure 2.5. SOA Practice (Adopted from Michlmayr et al.,2007)

By implementing the SOA approach into an application, many benefits will be received by stakeholders and organization involved as widely discussed by IT peoples included the academic researchers (Liu, Wu, Patnaik, & Kumaran, 2009; Ma & Liu, 2013). 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 of 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 highly suitable for any modification and changes to

the system without disturbing other components to the system since its service interface is independent of 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 types of database and programming language efficiently (Raghupathi & Kesh, 2007).

These SOA characteristics could empower HLI system by supporting a wide range of business processes as well as for any changes of the business processes, even across heterogeneous IS and other departments. The advantages of SOA approach were agreed by Erl (2008) who viewed SOA as a way to be loose coupled software components or 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 flexibility, cost, and 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. Besides, the administration costs could consequently be reduced with better information visibility and can achieve business agility. 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). Therefore, an insight study of existing SOA models for implementation has to be conducted in order for succeeding

SOA project could be achieved. Thus, based on the previous sections of reviews, a summary of SOA-based system's characteristics is listed in the following table.

Table 2.1

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		☑	☑		☑		☑

2.3 Existing SOA Models

Realizing this, the successful SOA implementation requires a blueprint of SOA model or framework as a guideline to be started in the early stage of SOA-based IS development. The content of the blueprint is highly necessary to design and apply the strategies and processes involved (Robinson, 2008). In SOA domain, there are SOA maturity models and previous studies that had been proposed their own SOA frameworks and models for developing SOA.

Literatures had shown two 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 to clarify in understanding the SOA. On top of that, there are a number of SOA models for reference as well. One of them was proposed by Selamat & Kharusi (2009) as shown in the Figure 2.6. The figure depicts that it is

involved several layer and the main element is Enterprise Service Bus (ESB) as a transport to interoperate data among various IS. This model had shown the appropriate components and elements will be involved for SOA development. However, it is stills lack of explanation of how heterogeneous should be integrated to be a real time data updated. there is supposedly an optional whether to use ESB or not since there is another reference model by Aydin and Yalcinkaya (2011) that demonstrated that ESB as a role of transportation to exchange messages and could be replaced with another transportation as well.

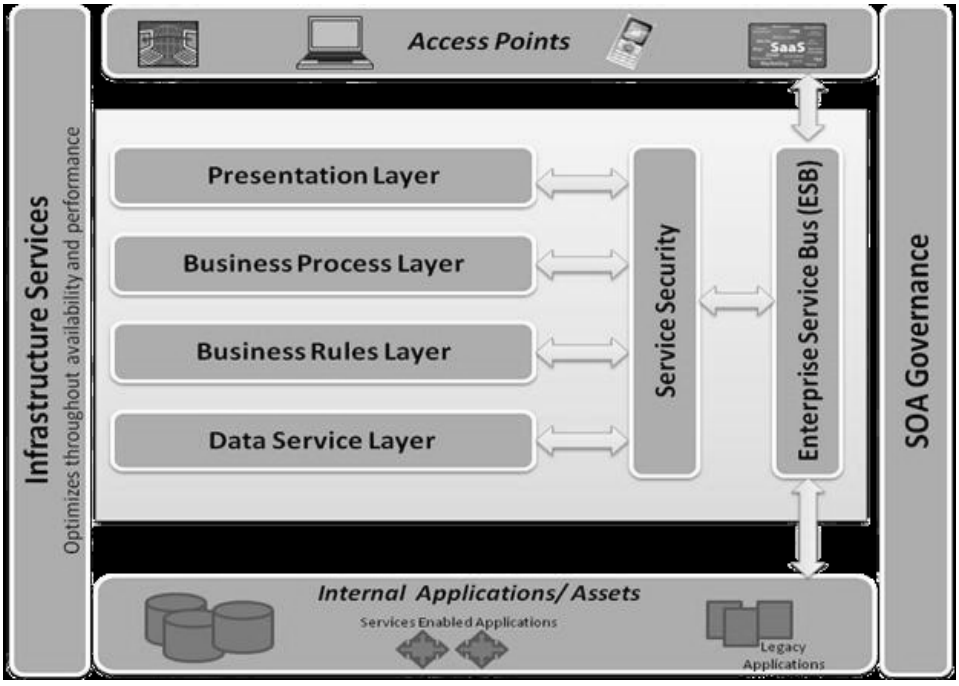

Figure 2.6. SOA Reference Model that proposed by Selamat and Kharusi (2009)

On the other hand, there is also another model could be referred 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). It describes SOA system designs and provides a mechanism for different IS stakeholders to understand

and participate in the construction of service enabled business processes. The design activity is supporting March and Smith (1995) statement, who mentioned that description of framework construction, is the first step in enterprise architecture. Hence, this model could be useful for SOA development as well. CAPSICUM model comprises of four main layers; access, process, services, and information are depicted in Figure 2.7. It has been applied in a case study at National Revenue Agency by Roach, Low, and D'Ambra (2008). This model had stated clearly which layer or part will be involved for integration services and gave a little idea of data integration but have lack of information of how should be the different type of data sources for example of heterogeneous IS environment integrate among them.

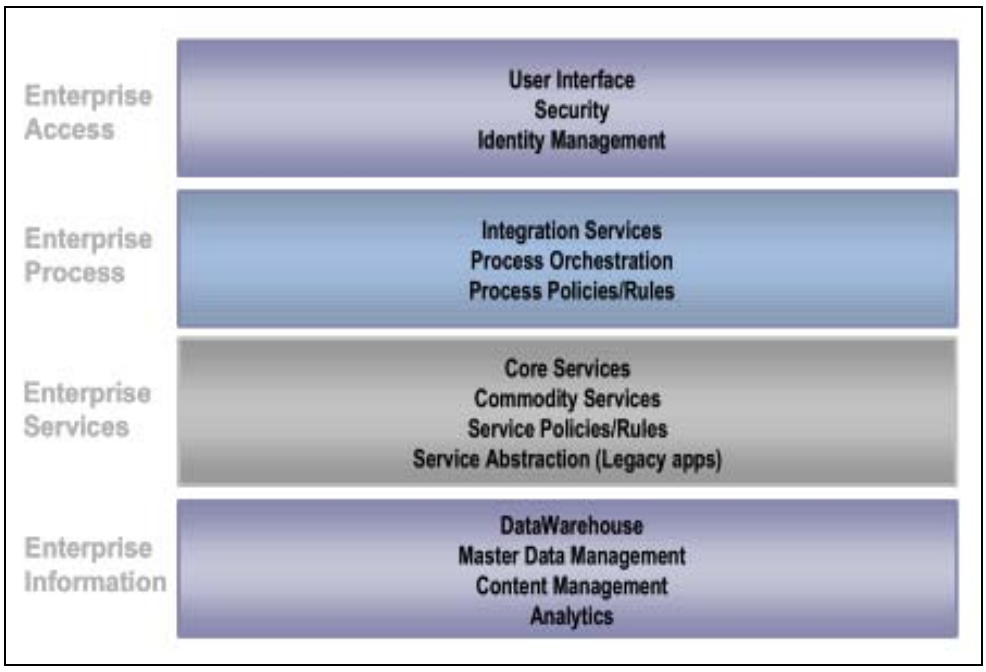

Figure 2.7. CAPSICUM Model, proposed by Roach et al. (2008)

Therefore, in solving IT and business problems by using SOA approach should be well understood its business and functional requirements. it is important to have a structured roadmap and the appropriate reference model in implementing SOA so that

its benefits offers are possibly being realized (Huang & Hu, 2004; Biemborn, 2008; Adam & Doerr, 2008). It is evident that in SOA projects, which in most cases span over a number of departments and enterprises, require an appropriate model as a guideline for implementation.

Even there are several SOA models that had been proposed by previous studies but in fact, some initiatives so far have failed to enable this alignment (Choi & Ramamurthy, 2011). This is because most of the proposed conceptual models were still lack of information and guideline details as well as lack of empirical validation for the case of heterogeneous IS integration. It has been argued that good quality of conceptual models has to be proven by empirical validation before being successfully used in practice (Moody, 2005). In relation to this study of proposing enhancement framework to integrate heterogeneous data sources, there are discussions on existing SOA models of heterogeneous IS integration in the next subsection.

2.3.1 SOA Models for Integration of Heterogeneous IS

There are several existing SOA models and frameworks for heterogeneous IS integration, for instance different data sources and programming language used since these two aspects always been a hot topic of IS integration research in IS management (Vdovjak & Houben, 2001; Balk, 2008; Börner et al., 2012). Reviews on the related previous studies are important to know what methods or technologies used for integration as a guide so that achieved the SOA implementation effectively. One of them that is Yan-heng et al. (2010), which had proposed a framework of data integration across heterogeneous IS environment by using XML and ontology into three main layers of the IS architecture (application layer, media layer and data source layer) as shown in Figure 2.8. Meanwhile, Huang et al. (2010) proposed a framework

for heterogeneous IS integration (refer Figure 2.9) as well but without using the ontology concept. It is more on data warehouse concept for collecting data from another IS. These two frameworks are compared and found that a similarity of technology used; XML but both of them have a weakness of latency time in updating heterogeneous data since there are not directly integrate with the involved IS, instead need to locate in a local data source first before distribute to the another data sources of IS.

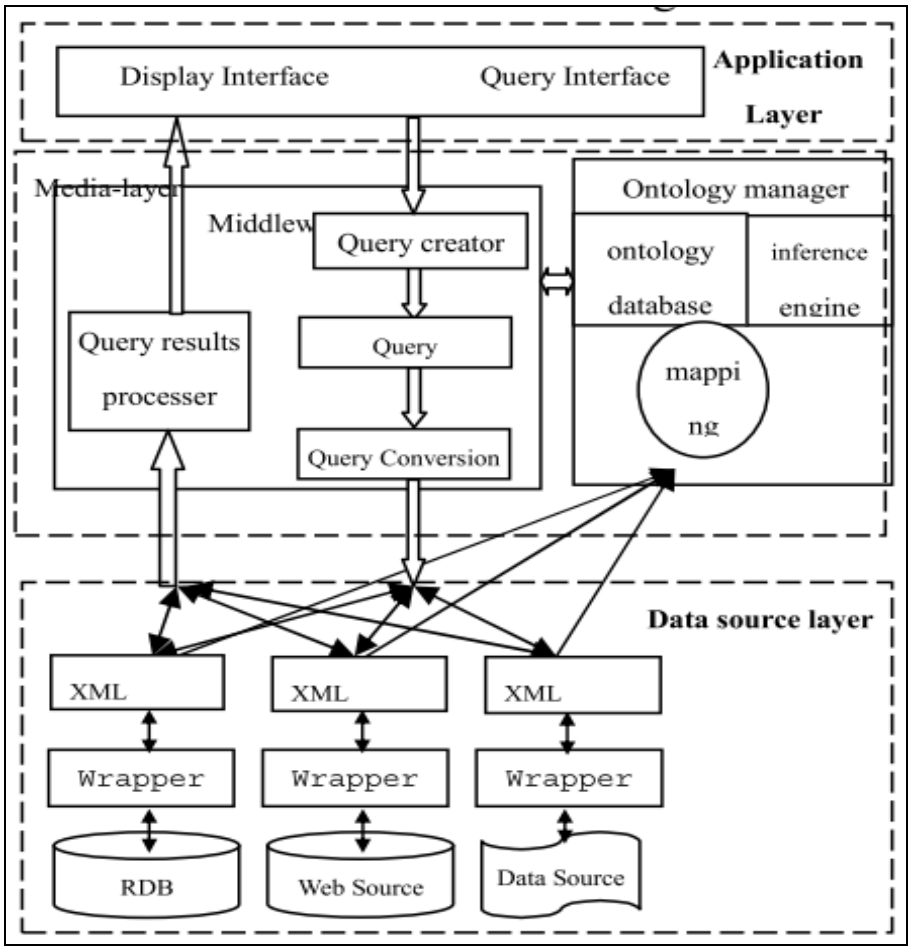

Figure 2.8. Framework by Huang et al. (2010)

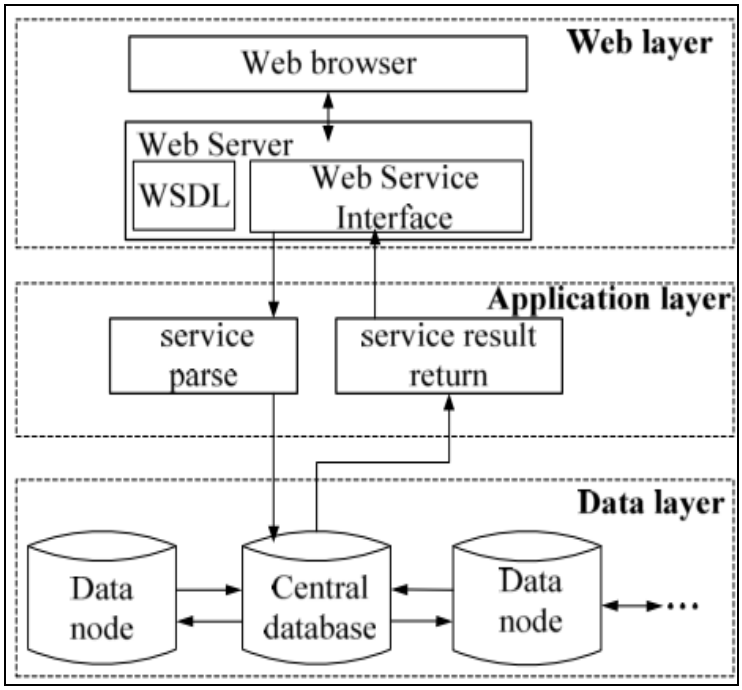

Figure 2.9. Framework by Yan-heng et al. (2010)

Then Li (2013) argues that a framework for IS development should be more detail in its description but easy to understand flows of the diagram. Referring to the proposed framework (see Figure 2.10), it seems a good design in general to be referred for the users to implement SOA. However, the data integration part had not shown a detail process or flow in terms of how it integrates the existing heterogeneous IS to meets the current business requirements. Albeit, Li's framework could provide a real time data updates by using WS technology without the central data source like in Figure 2.9 and ontology based (in Figure 2.8),which will be a latency time with that. Hence, an enhancement has to follow this path so that a comprehensive framework is achieved. As this study focused on HLI as a case study, the existing SOA models in HLI domains will be discussed in the next subsection.

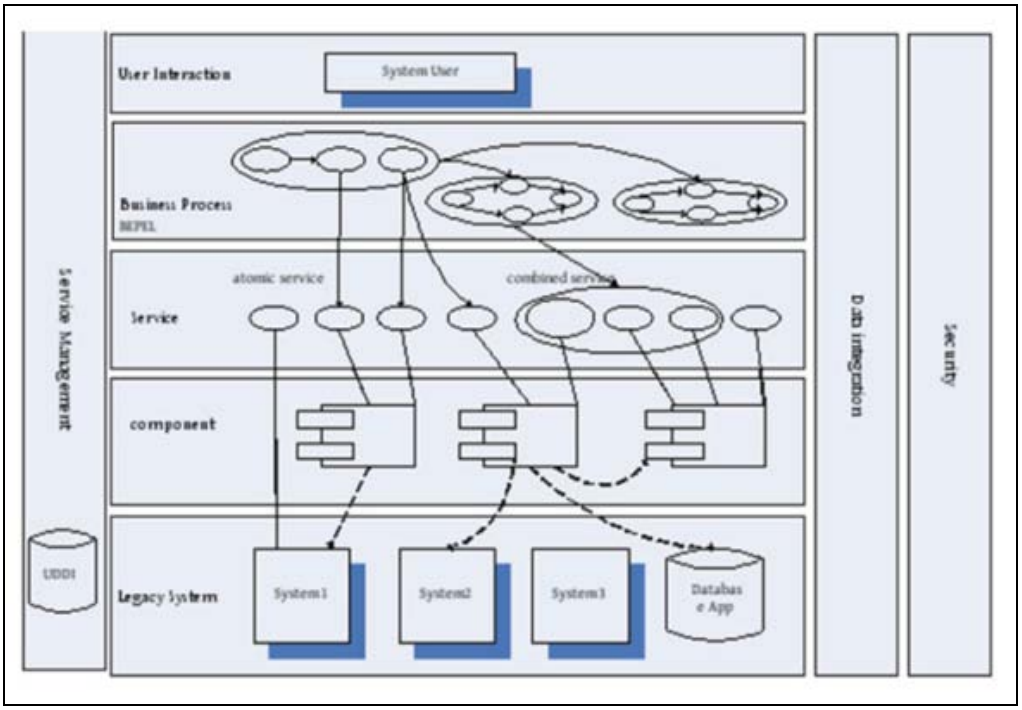

Figure 2.10. SOA Framework by Li (2013)

2.3.2 SOA Models for IS Integration in HLI

Many HLI (eg.: Lupu, Bologa, Sabau & Muntean, 2008; Pasatcha & Sunat, 2008; Ying-pei & Ting-ting, 2011) always need a more flexible and timely IS integration to avoid latency time in receiving information efficiently since most of them are heterogeneous IS environment. Yu et al. (2011) argues educational resources needs to be reusable and interoperable for sharing the resources across heterogeneous IS. A common method of transferring related data of an IS automatically into another IS like Learning Management System (LMS) in the HLI is very vital to smooth their daily business process. Many researches and articles published (eg., Kettunen & Kantola, 2008; Mok & Fong, 2008; Yihui, 2011) recently talking about SOA adoption in HLI domain. .A research conducted by Mason and Ellis (2010) found that SOA benefits a lot in HLI domain, and had been proven that a related IS turns into highly interoperable by implementing SOA.

The previous works have shown that many HLI have incorporated the SOA approach into IS development for integration, such as the University of Wisconsin at Madison, Embry-Riddle Aeronautical University, and Cornell University who had been succeeded in implementing the SOA approach (Eduventures, 2006). University of Wisconsin at Madison had accomplished to eliminate data redundancy, to get the information needed in real time, and had been improved their security for only limited the official data that had been authorized to be received. Meanwhile, at Embry-Riddle Aeronautical University, the adoption of SOA had contributed to a robust, highly agile, and scalable ERP system that can provides its globally dispersed staffs and students on real time with web-access services and improved the speed and accuracy of its business process. These efforts had saved sufficient cost and time in completing a process for the university. In the case of Cornell University, which earlier had a problem in integrating their different IS and silo tasks were improved the integration process and allowed users to view enterprise data dynamically across the different IS as well as to access componentized IS 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).

However, since a few years ago, several studies (Granebring, 2007; Selamat et al., 2009) argued that translating SOA-based system into a scalable and real time environment is quite challenging. This is because the guideline for implementing SOA into IS appropriately is still lacking (Alkhanak & Mokhtar, 2009). Hence, a detailed of SOA implementation framework has to be presented especially for integrating the heterogeneous IS in HLI. A study is also needed to further experiment

on how SOA adoption and its implementation into HLI IS for further leveraging the benefits (Kim & Yun, 2006; Mason & Ellis, 2010). There are some related works of SOA models for heterogeneous IS integration in HLI that are discussed as follows.

A study by Pasatcha and Sunat (2008) proposed a model of IS architecture that used SOA approach. Their model designed for supporting business processes in a HLI to be more flexible, centralized, ease to integrate the services of heterogeneous e-education systems and save the maintenance cost. They demonstrated the model by using XML, SOAP, and HTML as the communication protocol. However, the model was not validated with empirical validation of prototype implementation. Besides, the design is too general and could not show a detail of SOA implementation especially the part of integration among heterogeneous IS. Thus, it causes a difficulty to be a guideline in implementing SOA for the integration.

Similar purpose had been proposed by Yu et al. (2011), who used SOA approach to manage educational resources to be reusable and interoperable so that could share resources across learning communities. But, the different here is the usage of Linked Data-driven, which is used to exposed data across all application domains on the web.

2.3.3 SOA in Malaysia's HLI

SOA adoption in Malaysia is still new included for HLI domain but there are a number of HLI a year after year interested to implement SOA approach into their IS such as Universiti Putra Malaysia (UPM) (Yunus, Meseran & Wahab, 2012) and Universiti Malaya (UM) (Alkhanak & Mokhtar, 2009). Previous studies by Alkhanak and Mokhtar (2009) and Fang and Sing (2009) had proposed guidelines of SOA implementation frameworks in Malaysia's HLI environment.

Alkhanak and Mokhtar (2009)'s study, claimed that Malaysia is still having a small number of published studies of SOA and its implementation in HLI and their study just only implemented into a postgraduate student department (PGD) system for their university to be centralized system. The study proposed a SOA development framework (refer Figure 2.8), which used Howcroft-Carroll's Methodology in developing prototype and WS technology to convert the manual services into SOA-based systems and integrated the heterogeneous IS. However, the framework is not described details of how to integrate heterogeneous IS especially the different type of data sources used. Therefore, an enhancement of the framework should be conducted in providing a clarification of how to integrate the heterogeneous IS by using SOA approach.

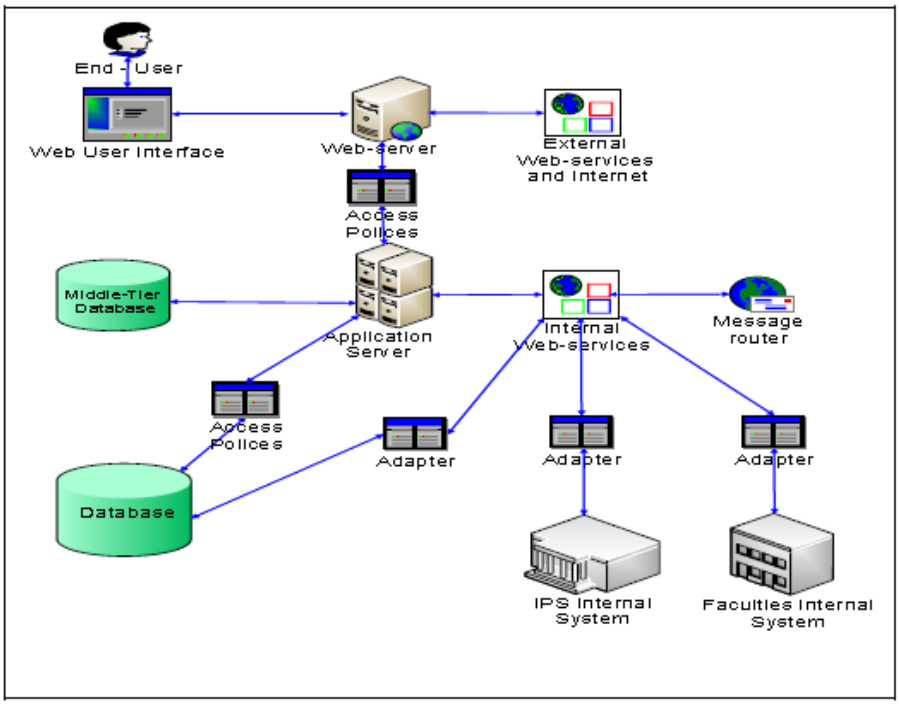

Figure 2.11. SOA framework proposed by Alkhanak and Mokhtar (2009)

The study's method used interview and questionnaire as data collection instruments, and evaluated by using three main factors of cost, time and users' satisfaction Alkhanak (2009). Those instruments are very important to get more information about

what SOA is it and how to implement into IS. It was successful to enhanced manual services of postgraduate IS into SOA-based systems. However, it should be considered consolidation of the previous SOA frameworks as well to be a strong support. Besides, the integration part of heterogeneous IS was not highlighted in the proposed SOA framework. Appropriate framework of SOA is crucial to ensure their effective implementation and positive impact on IS management in organizations. A review of SOA frameworks for heterogeneous IS integration in HLI's Malaysia that was carried out indicating that the improvement of current frameworks are required. In order to satisfy this requirement, this study is conducted to enhance the framework of SOA for heterogeneous data sources integration. The framework can be potentially used as a guide to conduct better and comprehensive SOA implementation.

2.4 Factors of Succeeding SOA for Malaysia HLI

Implementing SOA-based system will be started in the first phase of analysis and referring to Josuttis (2007), the keys to SOA success is design process and systems architecture. This is also needed to consider business process requirements in the initial phase and followed by a good system design methodology. Here an appropriate framework or model is needed.

2.4.1 SOA Frameworks and Models

A good quality of a conceptual model is the main factor of SOA successful implementation in practices. It is a blueprint of the IS that would be developed. Besides a conceptual model, there have a framework used and very crucial to have it as a road map and guide to implement SOA-based system. There are many (rigorous theory-based frameworks to speculative frameworks) conceptual models for IS

standard that highlight the quality of the conceptual model representations and process such as the 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 recognition of a problem situation to be addressed with a simulation model to a determination of what is going to be modelled. Inappropriate planning will make SOA implementation costly and complicated. Therefore, reviews on the existing conceptual models and frameworks had been done and discussed in the previous sections above so that it could be consolidated with the related and appropriate frameworks into the proposed framework. Then, before jumping into IS development with coding or implementation phase, some technologies that are suitable to be used also important to be considered.

2.4.2 Technologies Support

SOA will be more rigorous when implemented with powerful technology as a middleware or communication protocol that helps achieve the interoperability efficiency (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 helplines.).

Recently, WS technology has been widely used as a middleware so called as a mechanism in implementing SOA approach into IS to support interoperability (Selamat & Kharusi, 2009). WS technology has been a trend in SOA adoption in

various domain of IS development. Table 2.5 shows a summary of the most common technologies with their strength and lacks characteristics that can use to support SOA implementation.

Table 2.2

Characteristics of the popular technologies used in SOA implementation

Technology/middleware of communication protocol	**Characteristics**
CORBA	Solved integration problems without causing architectural flow (Stal, 2002).
DCOM	DCOM can be used on a platform that supports COM services (Raj, 1998).
EJB	The integration layer (Gabhart & Bhattacharya, 2008), EJB standard were restricted to the Java programming language (Pawlak, 2006).
WS	Independent infrastructure, loose coupling, (Petritsch (2006); Papazoglou & Papazoglou, 2008), can expose its component to internet (Petritsch, 2006), self-container, programmable web-enable application (Papazoglou & Papazoglou, 2008), provide services for third parties on internet (Petritsch, 2006)

In conclusion, WS provides a loosely coupled design (Roach et al., 2008; Nikayin, 2009) in which it is absolutely independent technology to be used in heterogeneous IS environment such as programming language (Abrams & Andrews, 2004). It could be utilized in developing systems (Garikipati & Lim, 2006; Roach et al., 2008) which suites with services that can be used within separated IS from several business domains. WS features are language and OS independent, which can build in different languages on a remote machine and client application. It accesses via standard internet communication protocols such as extended Mark-up Language (XML), Simple Object Access Protocol (SOAP) and File Transfer Protocol (FTP) over HTTP. Usually, WS uses standard technologies of Web Services Description Language

(WSDL), XML, Universal Discovery, Description and Integration (UDDI) and SOAP (Erl, 2005; Hayward, 2005). Most SOA-based IS developments used WS technology, SOAP, XML, and Java programming language to build service interface agent (Mok & Fong, 2008) so that can be interoperable IS. Besides, WS are 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 is used together with WS technology to support the integration solution (Pansa, Walter, Abeck, & Scheibenberger, 2010) rather than implementing with CORBA and DCOM. This is in line with Papazoglou and Papazoglou (2008) who stressed that WS is an independent infrastructure, loose coupling, and self-container.

2.5 SOA Validation Techniques

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 strong enough to be implemented in the 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 distributed system, which is built across multiple IS and enterprises. Validating a framework could be done by using a proof-of-concept (Gleich, 2011), in which this study is using - prototyping technique. The proposed framework needs to get feedback from the experts by interview them face-to-face because this method is the most effective method for test and verify the proposed framework and prototype. To not be bias, the experts have to be from both academic and industry persons in range five to ten persons (Grguric et al., 2010).

2.5.1 Prototypes Experiments

Most previous studies that proposed conceptual models, as well as frameworks have not addressed the prototypes experiments. This is coinciding with Robinson (2008), who found that many conceptual models and frameworks evaluation are lack of empirical validation like prototypes experiments. Study by Raghupathi and Kesh (2008) also decided to do empirical validation in a case study to realize SOA in practices as suggested by Moody (2005).

Moreover, this method was supported and proven by a study (Moreland, 2013) that had successfully conducted SOA validation by prototypes experiment of empirical validation. The validation techniques used is strong sufficient because this study not

only doing the experiments of its logical flow and theoretical, but also to give practical contributions. Besides, it gives an in depth understanding for the proposed conceptual model or framework through the experiments. Prototypes development for SOA-based IS also has several development methods.

2.5.1.1 SOA Development Methods

There have been many methods in IS development for validating the proposed framework or conceptual model such as Simulation Model by Robinson (2004). This method shows that analysis and design have to be done together in conceptual modelling process to produce a conceptual model or framework. This method gives a good idea to develop prototypes and conducted an experiment for validating the proposed framework. Furthermore, it has been referred by many domains such as game application, healthcare, and education (Robinson, 2008). The Simulation Model seems easier to read and understand the flow of processes. Therefore, to validate the proposed framework in this study, this method had been referred. Besides that, as this study proposed an SOA framework, it is need to consider the existing SOA development methods as well.

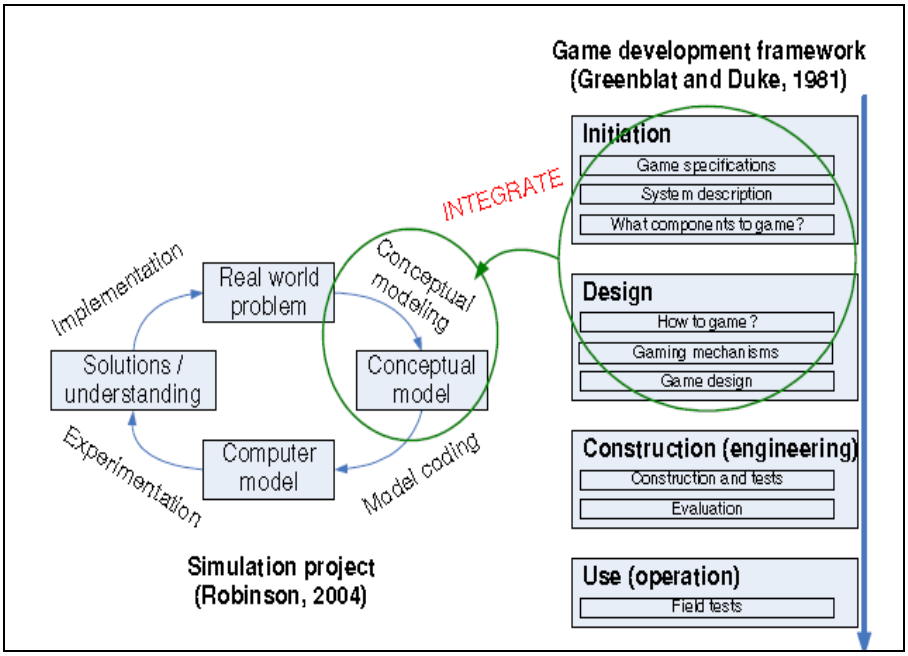

Figure 2.12. Simulation model (Adopted from Robinson, 2008)

Allen, Higgins, McRae, and Schlamann (2006), and Jeng and An (2007) outlined SOA development method into seven stages starting from service identification, service specification, service realization, service deployment, service execution, service monitoring and measurement, and service evolution and change. This method is more focused on services 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 Krogdahl et al. (2005) claimed that agile method is the best for SOA development such as BITAM-SOA (Kazman et al., 2010) and SOMA (Arsanji et al., 2008; Yu & Ong, 2009). However, Offermann and Bub (2009) proposed SOA-Method (SOAM), which has been claimed as a better method rather

than others existing methods, which had been validated by an empirical method comparison (Philip & Udo, 2009).

2.6 Summary

Some previous works provide evidences in applying SOA approach in the heterogeneous IS promised to have a high potential to be a better integration solution. These have been agreed by many SOA researchers and professionals where they had been adopted the SOA approach in their IS successfully. However, the existing SOA models and frameworks of heterogeneous IS integration still need improvement and more details to be a good guideline in implementing SOA successful. The required appropriate SOA requirements and models as discussed in previous sections are tremendously crucial for implementing SOA. On top of that, this chapter also analyses and compares the existing SOA conceptual models and frameworks; the standard IS design methods as guides to produce the best result of a suitable implementation framework for heterogeneous IS integration. 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. It is not only a collection of methods to perform a research, but it is also a systematic way to solve the problem as described in Chapter 1. The methodology in this study is designed to support the understanding on how to conduct this research so that the objectives could be accomplished. Accordingly, it is discussed by addressing the way this study constructs the proposed framework until its validity is achieved.

3.1 Research Design

This study used explanatory of research design as research approach and using qualitative methods to discuss the selected data. As for research strategy, a case study with prototypes experiment will be conducted. There are also doing in-depth interviews to get related information and validation.

From reviews, many researchers have applied general methodology for design science research by Vaishnavi and Kuechler (2004) that comprises of five phases starting from awareness of a problem, suggestion, development, evaluation and conclusion. This research methodology can be a guideline in this study. Several phases are applied as shown in Figure 3.1. The following sections described in details the techniques involved.

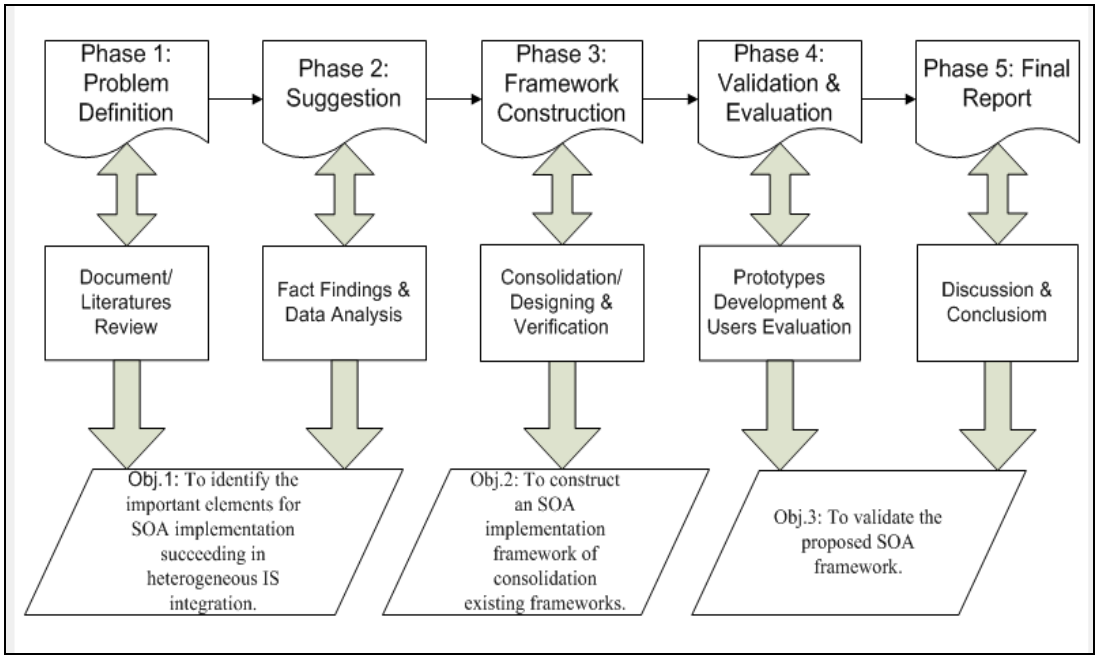

Figure 3.1. The research methodology (source: own work)

3.2 Phase 1: Problem Definition

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 gap of this issue; adopting SOA into heterogeneous IS and specifically integration of different type of data sources and programming languages. This study employed a qualitative approach since the data were gathered in the form of words, pictures, model diagrams and descriptions where these all provide a rich and deep description (Hartley, 2004). Besides, this is also applied to get the basic idea of the existing SOA frameworks or conceptual models for heterogeneous IS and defining its requirements. From the problem definition, some methods will be considered to overcome that problem as the following section.

3.3 Phase 2: Suggestion

Phase 2 involves two methods; reviewing the related literatures included document study (Whitten et al., 2001) and conducted interview (Sekaran, 2009) with related IS stakeholders of HLI and SOA experts that suggested by Kenneth (2004) for insightful investigation. These methods are so called fact-finding techniques.

Therefore, a preliminary study was conducted to survey current situation and issues in 19 public universities in Malaysia. A case study on IS in a Malaysia public university can be represented IS in Malaysia HLI. This is because, it was found that there is a similar issue; heterogeneous IS integration since most of them used various IS in their university. The case study course is according to the current IS issues as mention in the chapter one as well as chapter two. The interviews' forms were conducted in unstructured and open-ended format specifically involving the related stakeholders.

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 were aimed at providing in depth understanding of the current business and users' requirements in implementing SOA. The interview questions given to the SOA experts are as listed below.

i. What are your opinions about the IS issues today?
ii. Could you explain in details what actually SOA is about?
iii. From your point of view, what is the service?
iv. How to develop IS by using SOA approaches?

All the data were then analyzed using content analysis to generate the framework of IS with SOA approach. The results of the interviews will be discussed in Chapter 4.

The gathered data indirectly were validated by experts and that literatures review. Then, its outcome will be retrieved, which are the most important SOA elements for IS development with heterogeneous environment so that it will achieved the first objective of this study. Then, a content analysis was done to study the relevancies of the SOA characteristics for heterogeneous IS integration to construct SOA framework.

3.4 Phase 3: Framework Construction

This study explores the current IS architecture in the case study to be modified so that enable SOA-based system. Besides, the data gathered from the fact-finding before was used to improve the current architecture. Specifically, data related to SOA is used to answer the first research question stated in Chapter 1 regarding to identify the important elements for SOA implementation succeeding in heterogeneous IS integration. Then, a business process modelling will be used to describe what has to be done including input and output of a service that a part of business processes (Josuttis, 2007).

Results from the suggestion phase will be used to consolidate the existing SOA conceptual models and frameworks as a guide for the SOA framework construction processes (Aydin & Yalcinkaya, 2011). To verify the accuracy of the proposed framework, the expert review technique was carried out since expert review is more efficient than usability test (Molich & Dumes, 2005). The proposed initial framework was reviewed by the expertise. From the experts review, all suggestions for improvement were added and followed with a better framework.

3.5 Phase 4: Evaluation and Validation

As to successful implement SOA in this study, a case study and prototypes experiments were conducted. Therefore, a validation of the proposed framework is obtained by implementing prototypes of the case study as suggested by Robinson (2008) and it is also verified by the users and expertises.

3.5.1 Case Study

Integration heterogeneous IS had been discussed before in various domain with various technologies involved. SOA is a new trend of IS development approach that adopted among HLI in Malaysia, particularly in the public universities. Similar to other universities, the case study in UUM also has student information system, examination and graduation system and something related to student data as well as the university staff to support its business processes in the university.

This study has selected UUM as a case study based on three main reasons. First, UUM has various heterogeneous IS that could be represented others universities or HLI especially in Malaysia. Second, UUM is a management university, so it is in progress toward increasing quality and performance of the existing IS. Third, the university also has just undergone system restructuring, where 14 schools have been setup under three colleges. Due to these changes, the university is critically in a process of strengthens all IS especially those that are related to students affair and academic. Thus, this situation becomes the main reason for this study.

Therefore, three main student information systems of UUM have been chosen in this study. Then, the main findings will be withdrawn to others IS in the UUM and other institutions as well. The case study provides an in-depth understanding, and it needs

explanatory analysis (Klein & Myers, 1999) in understanding SOA and its requirements to solve the issues regarding the IS that not highly interoperable systems. This has been the basis for adopting experimental case study besides it is investigated in a specific case (Zainal, 2007).

Then it continues with an exploration of the documents describing the selected IS specifically ASIS, LZS and Library system from the Computer Centre of UUM. Analysis of the legacy IS in UUM were done in the early phase before recognized the service operation to be SOA-based IS. Data gathered by the organization's requirements, a consolidation of existing frameworks will be considered so that could have produced a good combination for a new framework to implement the SOA approach in integrating heterogeneous IS. Services design will be done with details and the process preparation of coding development will be started.

3.5.2 Prototypes Development

Prototypes development in this study has applied the SOA-Method (SOAM) that is proposed by Offermann and Bub (2009). Based on literature review, SOAM is better for SOA development of this case study rather than BITAM-SOA (Kazman et al., 2010), agile method (Krogdahl et al., 2005) and SOMA (Arsanjani et al., 2008; Yu & Ong, 2009) in aligning IT functions and business demands. SOAM is chosen to apply in this study because it involves consolidation of legacy systems phase and SOA requirements phase for a SOA framework construction. This method has several phases starting with the company and legacy system analysis, service oriented discovery, consolidation, and service design and process preparation (refer Figure 3.2).

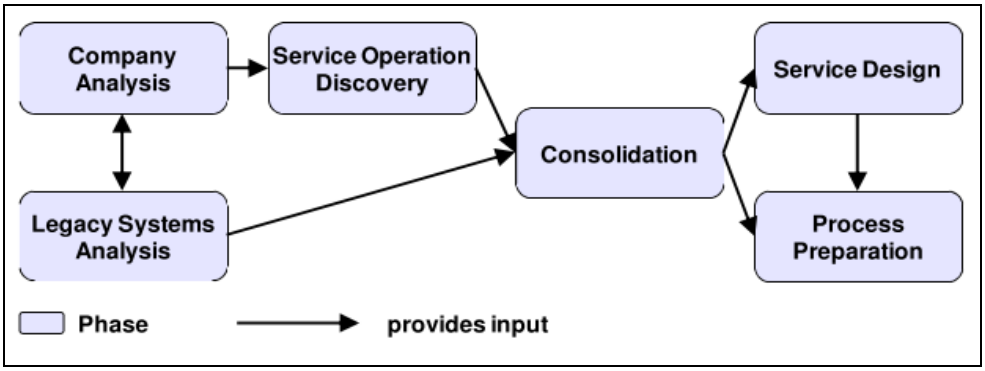

Figure 3.2. The Phases of SOAM (Adopted from Offermann and Bub (2009))

After analysis of the case study for the legacy systems and company analysis, prototypes experiments are conducted, which is involved coding, testing and debugging, and maintenance systems. During experimental, a throw-away prototyping also involved. Only the correct prototype was chosen to be used in the final stage of the experiments. Different prototypes were developed to validate the proposed framework, which is represented as heterogeneous IS, that used different type of data sources; MySQL, PostgreSQL and Oracle XE in testing the interoperability function of SOA approach. Additionally, the successful prototypes have also been evaluated by the application consultants from IT industry and stakeholders involved in the university.

3.5.3 Experiment of Prototypes

The experimental method was carried out to achieve the third objective of this study, which is to validate the proposed framework based on the SOA approach through prototyping validation. All features and functions of the prototypes will be evaluated by using questionnaires and interviews of empirical method. Besides, expert reviews also will be done to validate this prototype of the proposed framework. Additionally, implementing SOA into heterogeneous IS in a large distributed system should be done

incrementally so that if any failure happens, it is not too severe and not affecting the current activities (Shull et al., 2002) of the whole IS. Therefore, the experiments of prototyping are relevant and in this study, the scope of focusing on a small numbers of IS at a university rather than involving whole IS in all universities on an anticipation that all IS in universities are homogeneous.

3.6 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 with this, Table 3.1 maps the combination methodology phases and activities with the outputs that were supposed to be produced respectively.

Table 3.1

Summary of the Theoretical Relationship

Questions	Objectives	Methods	Outcomes	Validations
How to improve the existing SOA implementation framework for heterogeneous IS integration?	To identify the important elements for SOA implementation succeeding in heterogeneous IS integration.	1. Documents & Content Analysis 2.Interview SOA Experts & related stakeholders	Requirements (SOA elements) to successful implementation	Literature review analysis Experts review
	To construct an SOA implementation framework of consolidation existing frameworks.	1. Consolidation of previous SOA frameworks 2.Constructing an implementation framework to be incorporated with heterogeneous IS 3.Get consensus from expert reviews.	A verified SOA implementation framework	Experts feedback of the framework/documentation & their consensus
	To validate the proposed SOA framework.	1.Prototypes developments 2.Users (Experts & Stakeholders) evaluation	A validated SOA framework with the prototypes tested.	Prototypes experiments inf a case study & users' evaluation

CHAPTER FOUR
ANALYSIS AND DESIGNING FRAMEWORK

4.1 Introduction

This chapter describes the details about the data analysis and design to achieve this study objective. From Chapter 2 of reviews, it had demonstrated that the characteristics of SOA-based system is normally related to three quality attributes i.e. interoperability, flexibility, and modularity, which currently becomes the high demands in heterogeneous IS development. These characteristics could be a guide to achieve for SOA adoption in HLI. In fact, that was the motivation of this study in the beginning. The intention was driven by the needs to solve IS integration issues in the heterogeneous IS environment and will be discussed in this chapter.

4.2 Fact-findings Analysis

The unit of analysis in this study is an organization of a case study. A public university in Malaysia had been chosen with involved three different IS, which are LZS, ASIS and Library System as to be a sample of testing. The documents of the three systems were obtained from UUM Computer Centre. Several documents like ASIS and LZS module's documentation (including their system requirements, model and architecture), which are the main IS of Student IS (SIS) were analysed.

4.2.1 The Case of Universiti Utara Malaysia

Universiti Utara Malaysia has been established in 1984 as the 6th public university in Malaysia. After going through some restructuring processes, today UUM is proud to have three colleges with 14 schools; three post graduate studies, and several centre of

excellent (COE), institutes and students residential. Each of these entities' business processes are highly depending on several information systems, developed and maintained by the university's Computer Centre.

4.2.1.1 Information Systems Profile

Similar to other HLIs, UUM deployed various IS that are operated in heterogeneous IS environments with different types of data sources, platforms, servers, operating systems (OS) and programming or scripting languages. Among the major IS that supports academic matters in UUM are ASIS, Graduate Academic Information System (GAIS) and Learning Zone System (LZS). These systems have their own roles of business processes in UUM. ASIS is composed 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 other stakeholders. Similarly, GAIS consists of identical modules, but the focus is on the academic matters of the post-graduate students. Meanwhile, LZS is an IS to support teaching and learning information that frequently shared with several related other systems like ASIS and GAIS. Both of these systems, ASIS and GAIS, are frequently referred by other systems such as the Library System, LZS, and health system for data sharing.

The scope of this study is on the main IS related to students' academic matters, namely ASIS and LZS. Besides, the library system and GAIS are within the secondary focus. LZS uses the MySQL server database, Linux Solaris OS, Apache Web server and PHP programming while ASIS use the Sybase database, Linux OS, Enterprise Architecture (EA) server and server and Java script programming (JSP).

Since both systems are using different data sources, scripting languages and servers, it is difficult to integrate the data between them. Although LZS are located in various departments, colleges, and centres, the data are continually need to be updated with other IS, especially the main student information system (SIS) i.e.; ASIS and GAIS that are handled by the Computer Centre of UUM.

4.2.1.2 The Existing SIS Architecture

The main systems of SIS are depicted in Figure 4.1, which represents the core components in UUM systems' architecture. The figure depicts the SIS architecture with four main layers; front-end access layer, common services layer, data access layer, and infrastructure layer.

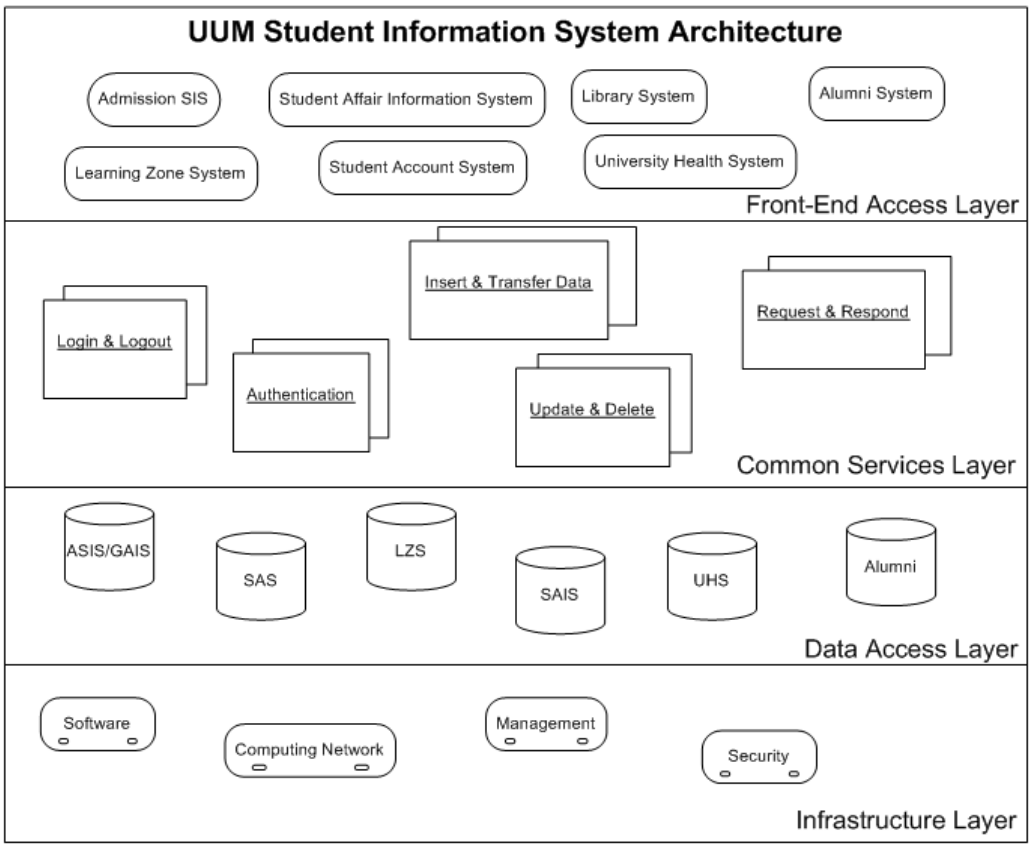

Figure 4.1. SIS Architecture of UUM Systems

a) Front-end Access Layer:

This layer refers to 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 ASIS, 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 log out, it needs the authentication service to authenticate matric number or identification card number to access services against a single authentication repository, such as a service is not incorporated in the front end systems, but rather developed as a common service to be used by the front end system. Also, this layer provides insert, delete, update, and transfer capabilities of the systems, particularly for managing their database. For transferring service, updating 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 interfaced 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 part of this layer includes the operating systems and their low-level services such as web hosting and email provider, database hosting, and systems and network management.

However, the story is a bit different with LZS, which has been operated since 2009 (Tahirah, 2011). It is a new infrastructure that makes use of the Advance Data Exchange (ADX) in integrating data from a number of IS specifically ASIS, GAIS, and Personal IS (PERSIS) (system for staff details) as shows in Figure 4.2. In short, LZS extracts information automatically without the person in charge to key in. There are two main IS integrated with ADX tool; university database, which is mostly used by ASIS and LZS that consists of several modules. LZS is used by students and lecturers for their learning and teaching purposes as well as students' data records. On top of that, students also have their own portal, where they can update their personal data.

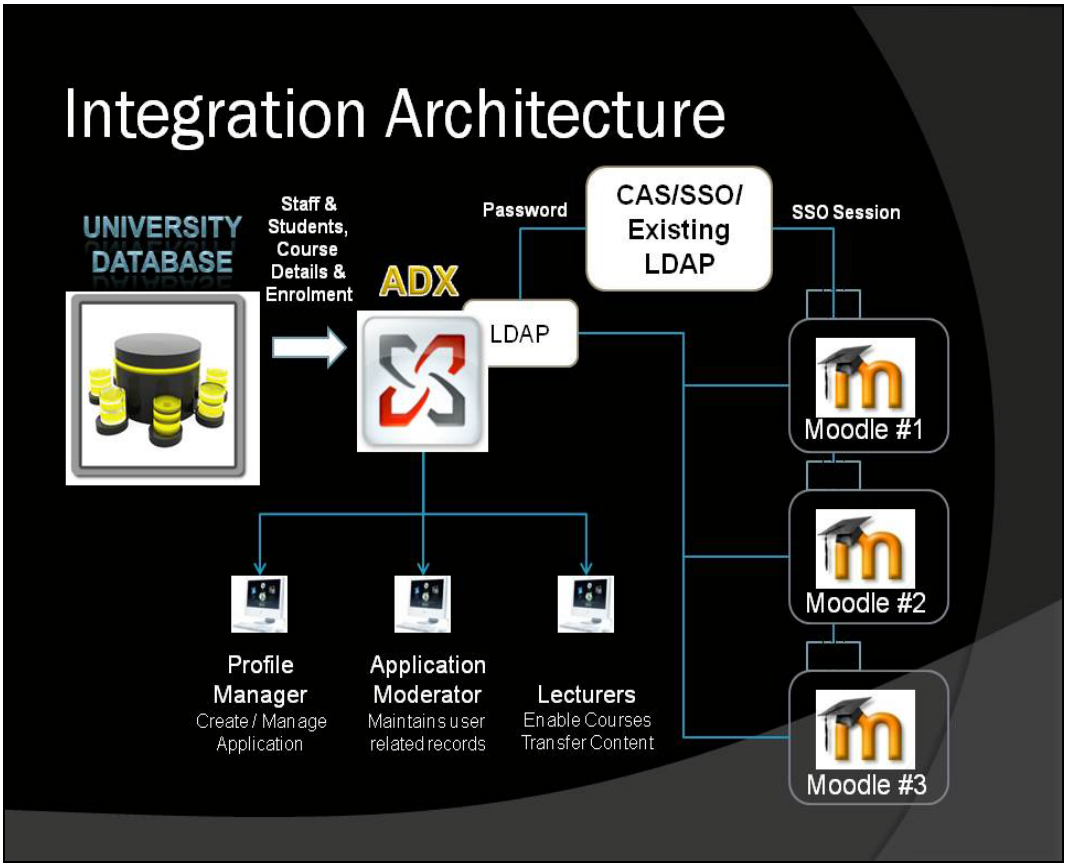

Figure 4.2. LZS Architecture

However, ADX uses batch processing to synchronize systems at regular intervals, which is not able to fully interpret in huge data to update all the data in the involved data sources in a timely. Therefore, it updates only once a day. As a result, when users need real time data, there is cumbersome to get data updated in real time. Also, it is only applicable in LZS with several related IS since ADX tool has to be installed in each two IS for their integrated communication. This means the system is not fully interoperable and took a high cost to integrate with other IS (Tahirah, 2011). Therefore, alternative integration is very crucial.

As a conclusion, every IS in UUM has its own architecture with different technologies and platform used. In detail, its logical architecture is tightly coupled among four layers; infrastructure, domain, application, and presentation layer, which is hard to

directly integrate for the heterogeneous IS. The overall SIS architecture is not fully interpreted, 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, a design of IS with high interoperability is particularly useful for sharing and updates the data in real time and make heterogeneous IS integration efficiently (Granebring, 2007). Therefore, a study to improve the current IS integration approach in the HLI need to be done. The next section further describes how existing SOA frameworks could be consolidated to help to enhance the SOA implementation framework for heterogeneous IS integration.

4.2.2 The Consolidation of SOA Models

The review of literatures in Chapter 2 has identified the important elements to enable SOA-based system. Table 4.1 depicts the main SOA elements with its principles as stated by Erl (2008).

Table 4.1

The Important Elements for SOA Implementation

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

The main SOA elements stated above had been identified from the previous SOA conceptual model. On top of that, several elements and other components also play an important role in succeeding the SOA-based systems. Figure 4.3 depicts the consolidation conceptual model with SOA elements support regarding to the discussion in Chapter 2.

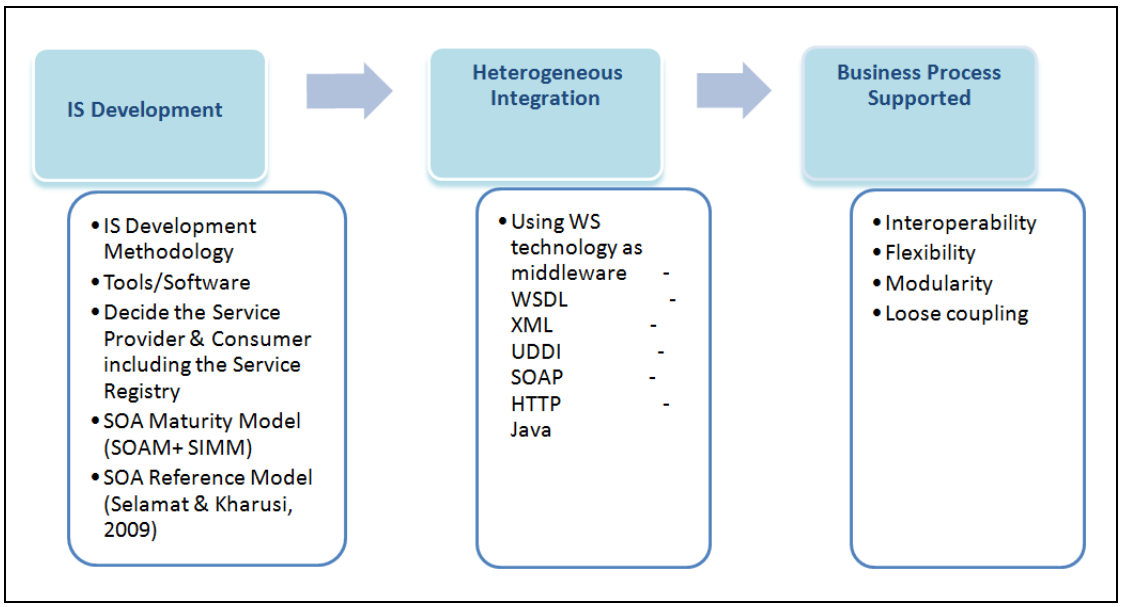

Figure 4.3. Conceptual Model for SOA Requirements (Source: Own Work)

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. the aim was to obtain insightful understanding about the heterogeneous IS in UUM. At the same time, several interviews were also conducted by SOA experts to get more information about the SOA approach 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 relates 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	Manual Data Entry
GAIS	Linux	JSP	Sybase	ASIS
Alumni System	Windows	PHP	MySQL	Manual Data entry
LZS	Windows	PHP	MySQL	ASIS, GAIS. Manual Data Entry
Library Systems	Windows, Linux,	PHP, VB, JSP,	MsSQL, Informix	Manual 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. Manual Data Entry
Student Account System	Solaris	JSP + Power Builder	Sybase	ASIS, GAIS, Manually Data Entry

The heterogeneous IS created challenges in performing the 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 implementation framework. According to the interviews, the person in charge at each SIS; ASIS, LZS and Library System

stated that they need a smart integrated system so that the 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) for instance, to repeat tasks, wasteful data storage and cost of operation could be reduced. Although there is a need to integrate system, 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 expert's interview are summarized as follows in standardized open ended interview question 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 flaky 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 SOA is. As a summary, the services oriented purpose is to fix the layer of the legacy architecture to be a single sign on. SOA is a journey of architecture to align IT and business gap. An SOA expert suggested 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 flexible, 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. The web service is one of interface pattern or method as easy as Lego; it can be plugged in because the standard interfaces. SOA can be a small project and when involved enterprises it is 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 the service, this question try to clarify what is service actually in SOA. An expert suggested that everything existing component should be serviced. Service is where somebody makes a request, and the service provider will provide the services (respond). Then here the process is not necessary again (user/requester should not see the process). Nowadays IS in the organization is moving toward service orientation. Figure 4.4 depicts the service concept.

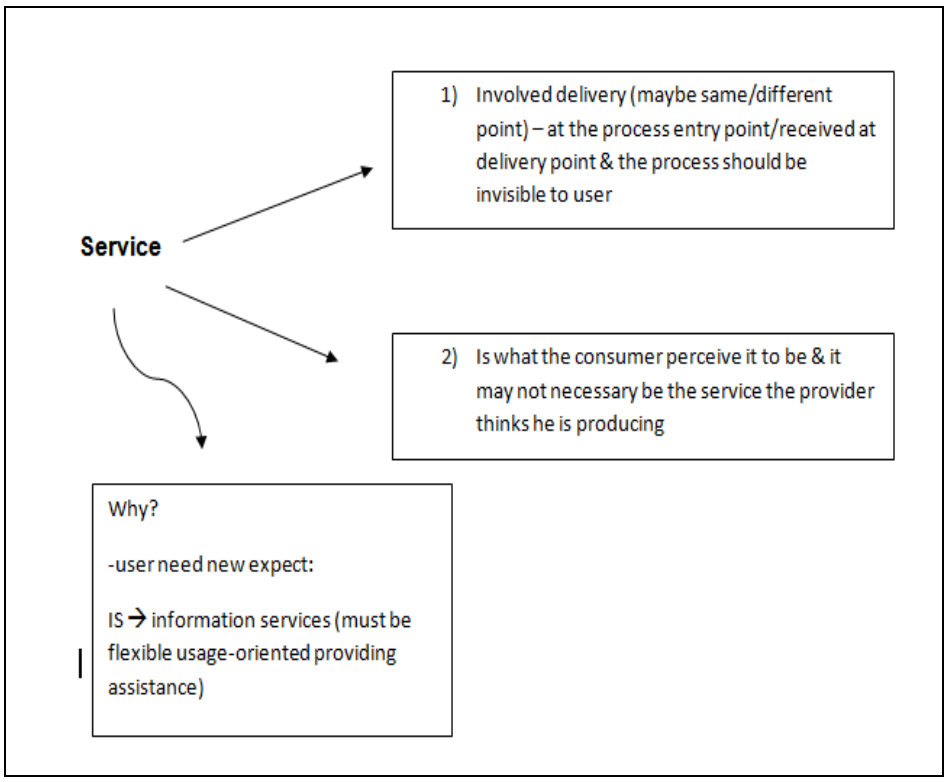

Figure 4.4. Service Concept

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

This question attempts 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 implements a 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 to use top-down approach methodology so that the bottom one will know by achieving the top one first (its mission, vision and goal). Figure 4.5 depicts the top-down approach, in which the suggested methodology is to be used.

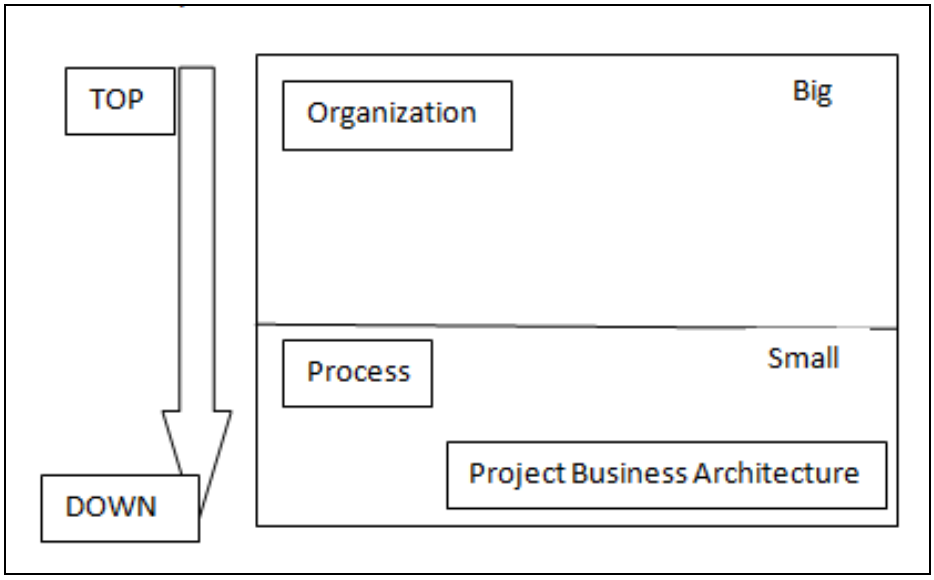

Figure 4.5. Top-Down Approach

6) Conclusion

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

SOA enables businesses to follow information technology by identifying the business services. Then to add or remove the component, it is up to customer's demand. The 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 applications (reuse) and can change something of services, but it must be in a standard language. The results from the interview will help the researcher to create a framework 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 literatures discussed in Chapter 2 will help to decide what technology to be used to implement SOA in SIS. Hence, this study uses a top-down approach in implementing 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 approach comes as a service-based to interpret the various data among the heterogeneous IS. This explains that the focus of this study at the Data Access layer of the architecture in Figure 4.1. It is an essential part of 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 a 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 Designing

As the first step in developing SOA-based IS, 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 are meant to be expressed in the forms of design principles during construction of SoSIS framework with SOA approach.

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 so that it can ultimately achieve data integration and information sharing (refer Figure 4.6). The SoSIS architecture is presented and discussed in the following section.

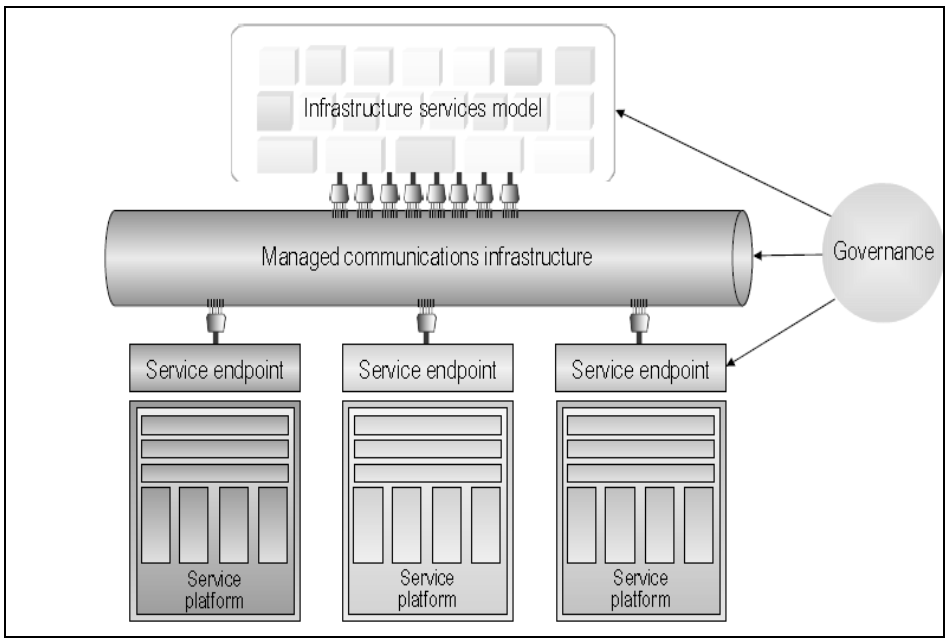

Figure 4.6. Joint service of SOA approach (adopted from Anne Thomas Manes,VP & Research Director of Burton Group, 10 Jan 2008)

4.5.1 Architecture for SoSIS

The SOA approach comes as a solution to share and integrate the data among heterogeneous IS. Particularly, the focus of this section is to design architecture of SoSIS, which is an important part of the SoSIS technical framework as it is used SOA approach and involved several components to become a complete IS architecture. Figure 4.7 below shows the position of IS architecture in the process flow to develop the system prototypes.

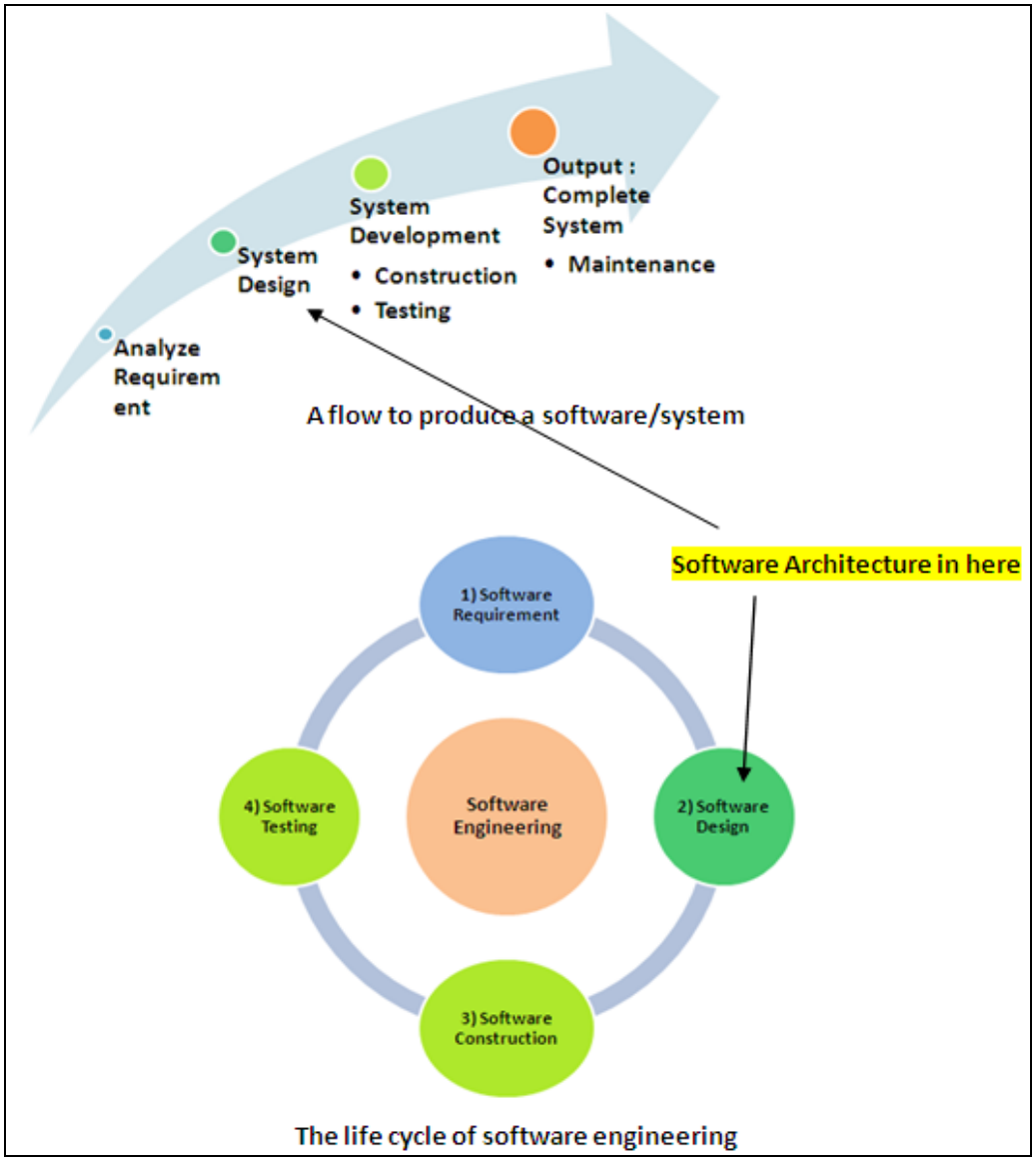

Figure 4.7. IS Architecture in Designing Phase

As mentioned in Section 4.4, WS is used in SoSIS to ensure the systems in the heterogeneous environment can interpret. In conjunction, Figure 4.8 shows the proposed SoSIS architecture that is applied in enhancing the technical framework of SoSIS consists with four layers starting from the bottom level; data sources, services, application, and presentation.

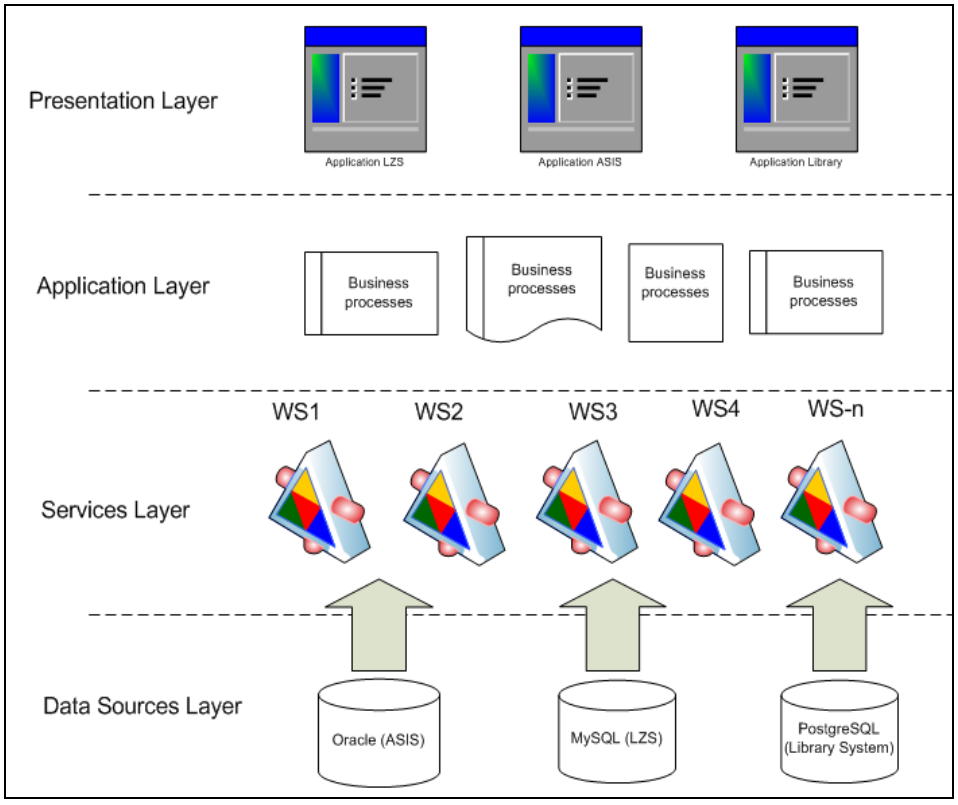

Figure 4.8. The Proposed SoSIS Architecture

4.5.2 Framework Construction

In this study, the focus is on the works proposing on an automated data updated into different types of data sources in several different IS. To enable various types of data sources to easily communicate or connect to each other, the components should be loosely coupled, and insured with high interoperability. Practically, SOA approach

comes as a service based to interpret the various data among the heterogeneous IS. Hence, there is a need to focus on the SoSIS data source model of Data Access layer, which is an important part of the IS architecture.

Having the requirement ready in the previous sections, the study proceeded with proposing a SoSIS implementation framework while doing prototyping experiments to explore SOA adoption into the heterogeneous IS. Different tools and standard technologies that support SOA functionalities were applied towards determining the suitable solution for implementation. Figure 4.9 shows a SoSIS deployment diagram using WS technology by focusing on ASIS and LZS.

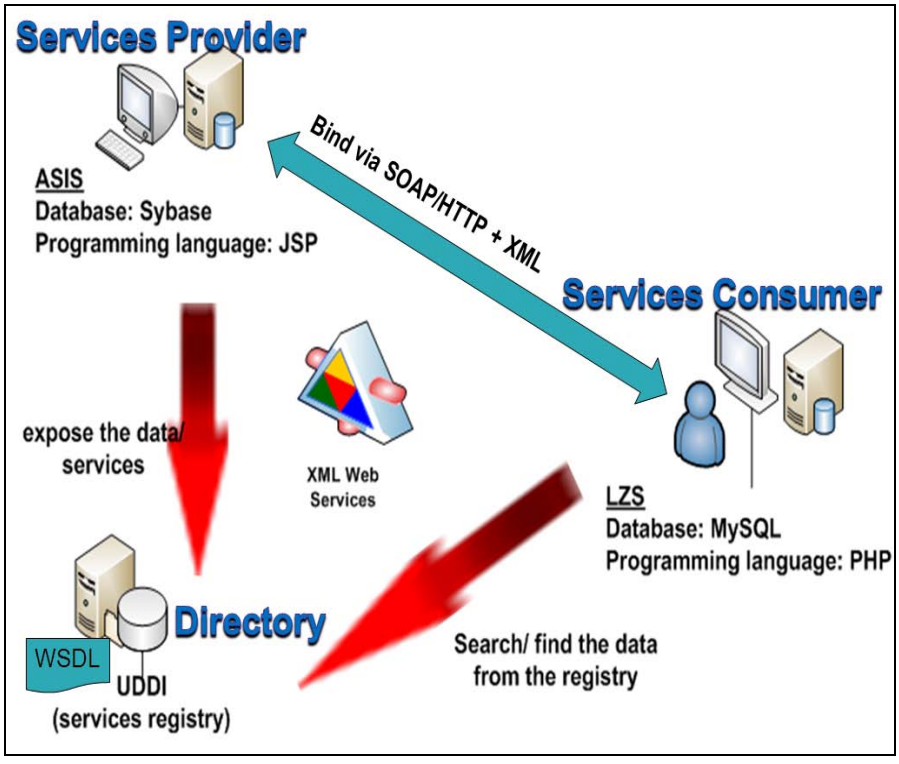

Figure 4.9. Deployment Diagram of SoSIS Integration

The implementation framework was conducted to outline how SoSIS achieves the interoperability and flexibility purposes. First, the flexibility is achieved by using the standard Hypertext Transfer (or Transport) Protocol (HTTP) transport (as shown in

the Figure 4.9) 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 have data source type independently, and so if the low level data source that holds the Student Registry is changed from e.g. Sybase to MySQL, then change is not required either to the web application or to ASIS.

An implementation framework is created from SoSIS integration deployment as depicted in Figure 4.9. Practically, SOA characteristics specific services, loose coupling, and interoperability were contributing to the valuable benefits that were discussed in the previous sections in this chapter. In conjunction with that, to realize the implementation framework of SoSIS (Figure 4.10), different elements are presented that constitute to the framework. Each element would satisfy one or more requirement and leads to the achievement of the goals of the framework.

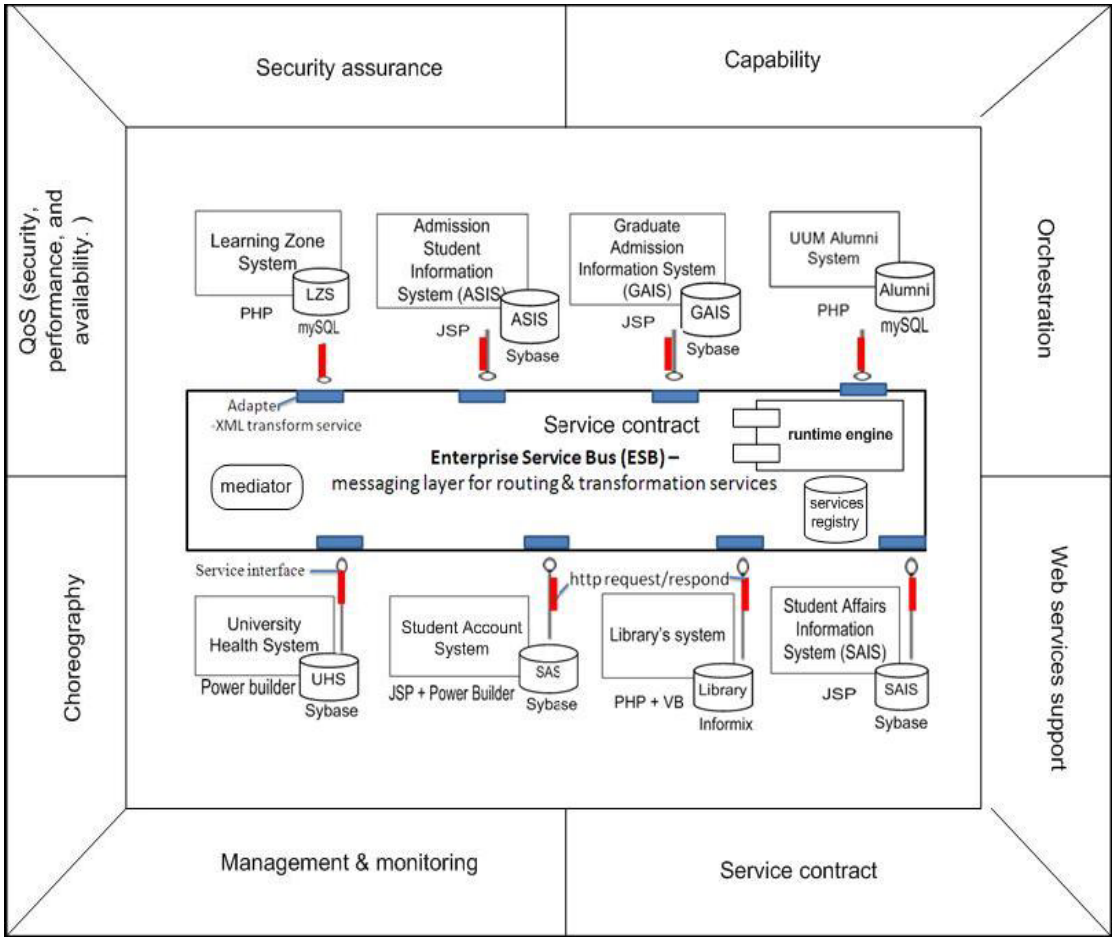

Figure 4.10. Initial Framework of SoSIS

The following describes the elements of the proposed framework

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 systems are built on a similar platform and programming language as well as database. Therefore, 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 (WS-Policy documents) 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 focuses on the heterogeneous systems and need to decide the software or tools which are suitable to implement the SOA approach into SIS.

e) Orchestration

When an application applies SOA in the current era, they most probably use WS. In a 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 necessary 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 externally 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 a 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.

4.6 Summary

In this chapter the current scenario SIS and its requirements, the core part of the UUM IS are discussed in detail. SoSIS solution is proposed to overcome the shortcoming of the currently used that lacks interoperability and flexibility. The discussion in this chapter explains that the framework 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 the 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
RESULTS AND DISCUSSION

The results of the evaluation for the proposed implementation framework had been discussed in this chapter. The validation was conducted by the experts and supported with prototypes experiments that evaluated by users. The processes of these validation and discussion are presented in the following sections.

5.1 Expert Review

The experts review commenced iteratively as early as in the beginning of the framework construction. It continued until the best result for improvement was obtained. For the first step after finishing the framework constructing (as depicted in Figure 5.8), SOA experts (academicians) from two universities in Malaysia were referred to. It was followed with some improvements on the framework as suggested by the experts. Besides that, this study also includes the SOA experts from IT industries to review as well. They were asked to evaluate and comment the proposed framework given in the Section 4.5.2 (referred to Figure 5.8) so that it could accept to verify the framework based on SOA. As a result, a new framework was constructed appropriately for implementing SOA into SIS of the case study.

Table 5.1

Result of Experts Review

SOA Experts	Comments
Expert 1	More description needs to add in understanding the framework. Also, good to add the important part of the code.
Expert 2	Have to be cleared on the technical part so that readers can understand how to develop SOA in a case to integrate heterogeneous IS.
Expert 3	Better to reconstruct to show the flow of the interaction among the heterogeneous IS in the framework.
Expert 4	Not bad in general but need to add in details about all the involved elements in the framework, which is at least involves the main SOA elements like a service provider and a service consumer for explaining how they interact each other using SOA approach.

5.1.2 The Revised Implementation Framework

Based on the comments and suggestions from the SOA experts above, several modifications had been done on the proposed framework. Based on expert's suggestion, the framework was reconstructed to show the flow of the interaction among the heterogeneous IS by using example of three main heterogeneous SIS from the case study. Some elements in the initial framework (refer Figure 4.9) were combined with a group of elements' name, and the diagram design became more comprehensible and clear. The modifications were as follows:

1. The choreography, QoS and orchestration components in the initial framework were categorized into Monitoring & Management component.
2. Security assurance is under security that contains all related elements with the security.

3. Web services supported was shown in the interaction process of integration, which is marked with number ①, ②, and ③in 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 framework combined the involved architecture layers as proposed in Figure 4.7 so that could show the mapping of each layer with the main elements. The layer of abstraction for SOA is focused in the service layer, which are consisting orchestration, business and application service layer.

Then the new framework is re-evaluated by the same experts until got a consensus from them. In overall, a result of the final evaluation, showed that all the experts agreed and satisfied. In accordance, a validated SOA implementation framework is illustrated as shown in Figure 5.1.

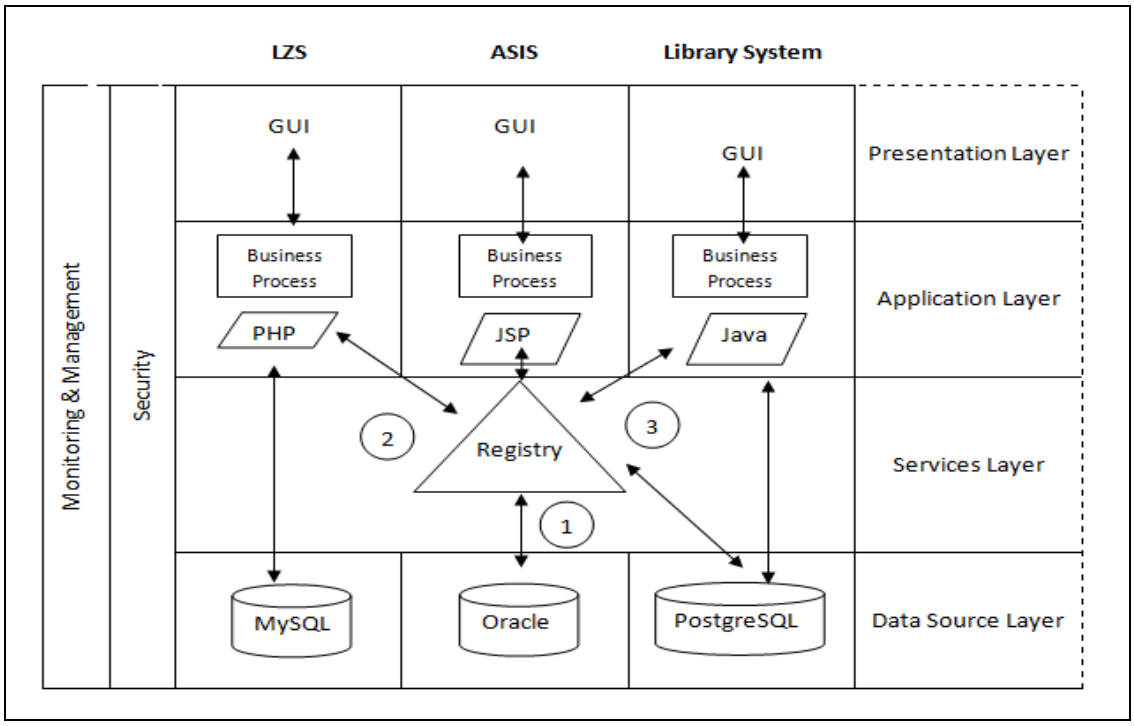

Figure 5.1. The Proposed SOA Implementation Framework

The detail 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 with the number one, ① shows services description; WSDL used for publishing the service (data that will be shared). In WSDL, there is one or more services contract. The services contract will describe the 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 heterogeneous IS could be found easily.

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

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 Users Evaluation

After evaluated and verified by the experts, the proposed SOA implementation framework has also been validated by conducted prototyping experiments, which is then evaluated by related users. In reference to that, the prototypes were developed for the selected SIS from the case study to test the SOA implementation. In conjunction,

three different IS with heterogeneous types of data sources and programming languages were selected for validating the proposed framework (refer Figure 5.1). All the prototypes have been developed successfully, and then successfully run to test all the functions. The prototypes were evaluated and tested by two IT application consultants from Malaysia who have experienced more than five years in dealing with SOA and WS development. This evaluation was also being contributed by four persons in charge of the three selected SIS from the case study so that users' evaluation contributes a strong validation for the proposed framework. 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 of the case study. It is built on Spring Hibernate and JSP programming language, and Oracle XE was used as 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 ASIS business processes while Figures 5.3 and 5.4 exhibit two snapshots of the prototype.

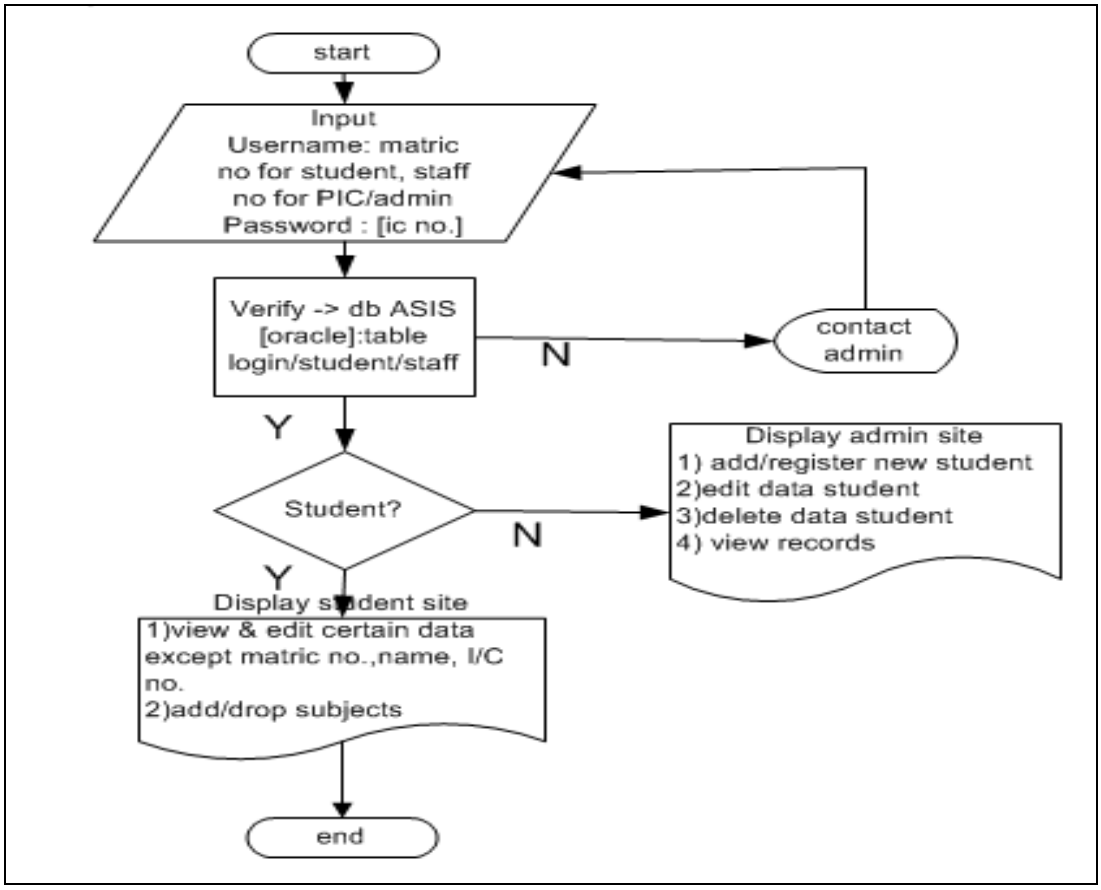

Figure 5.2. Flow chart of ASIS Main Functions

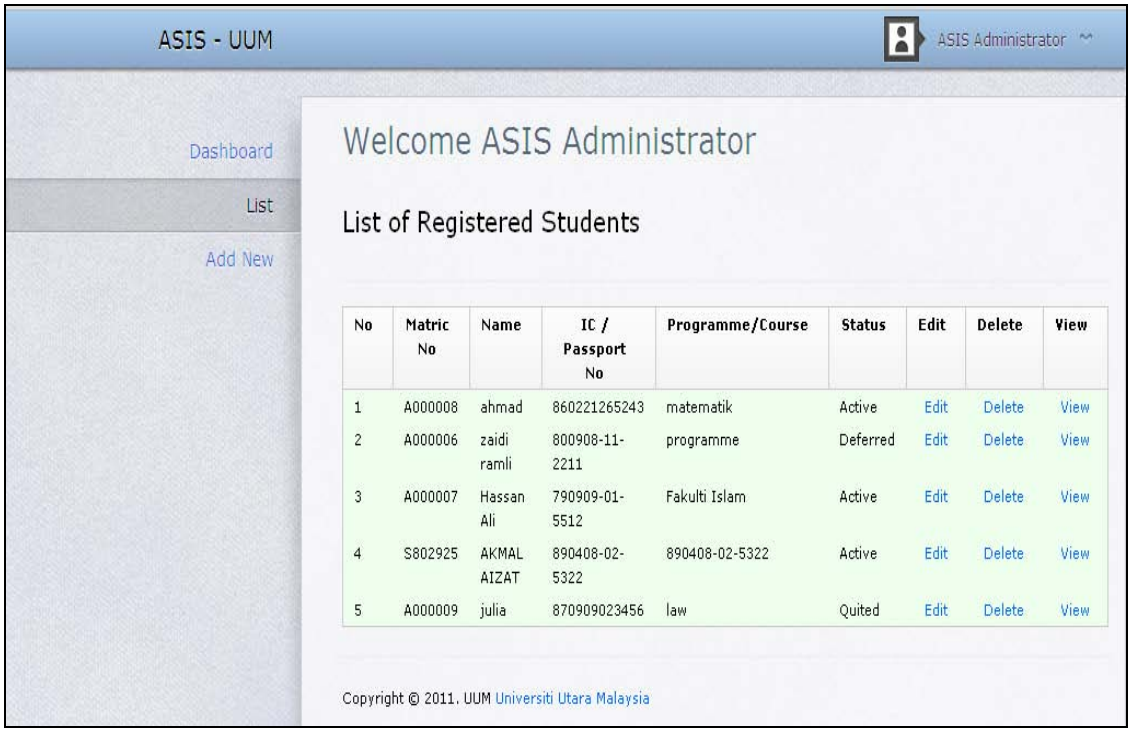

Figure 5.3. The Student List' Page

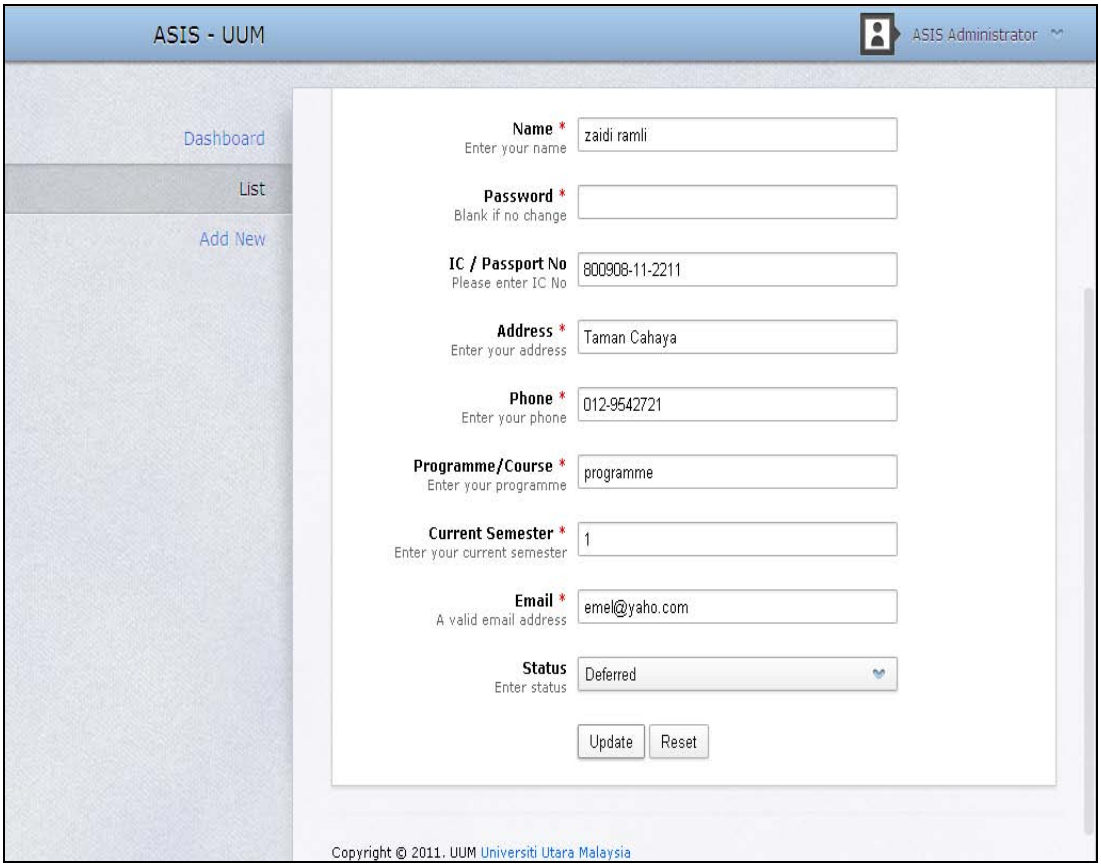

Figure 5.4. Online Form for Entering New Student Data

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 depicted in Figure 5.6 and 6.7.

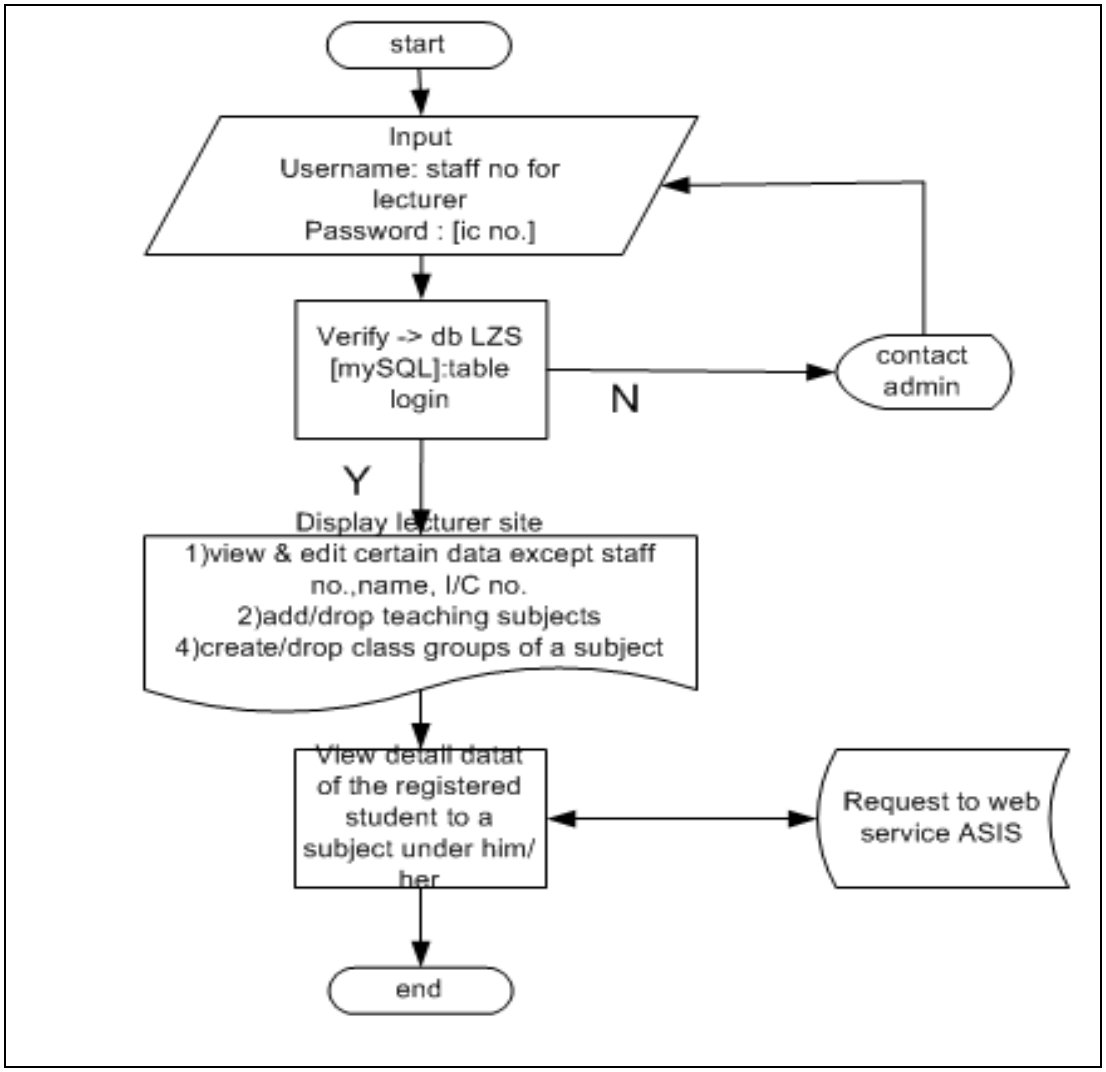

Figure 5.5. Flow chart of LZS Main Functions

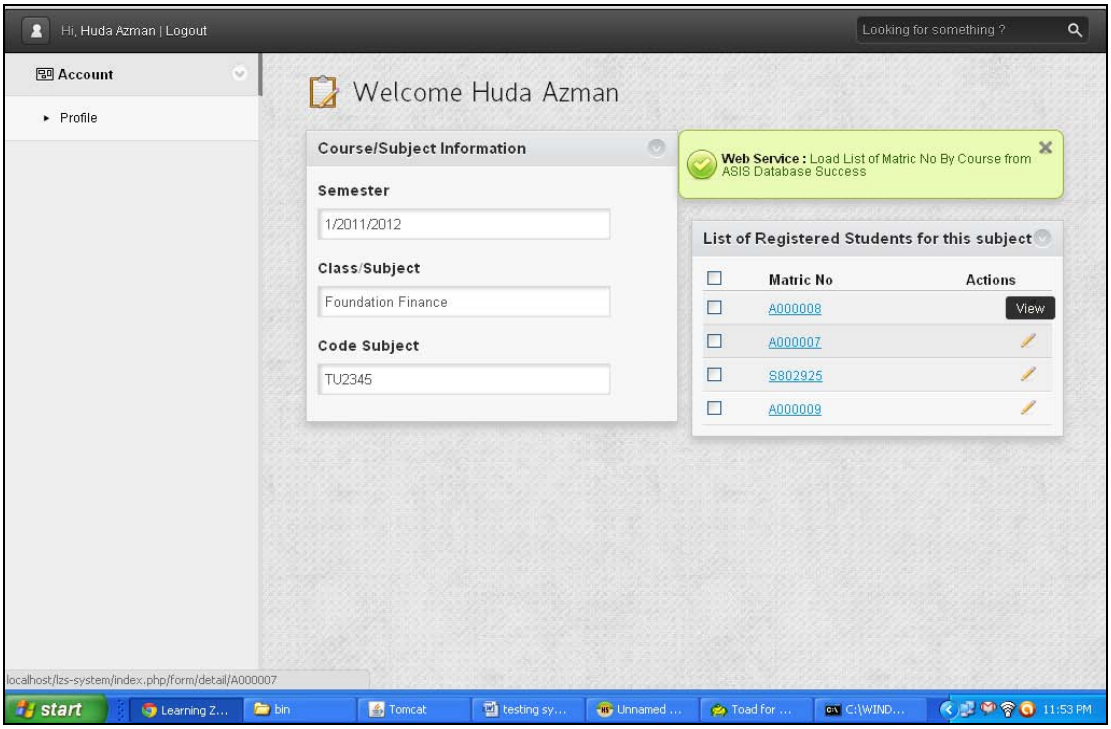

Figure 5.6. The Real Time Integration with ASIS

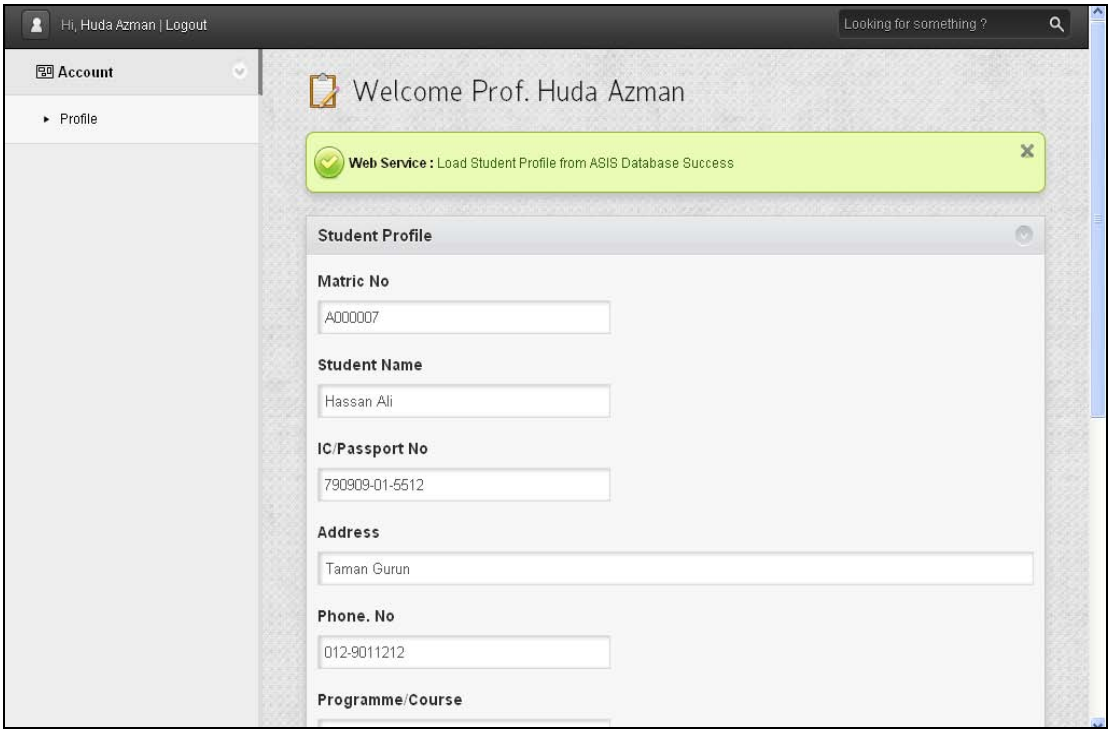

Figure 5.7. Student Profile from Lecturer View of LZS

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 the Library System. This prototype was developed using Java programming language and PostgreSQL as its database. The business processes 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 the data from ASIS.

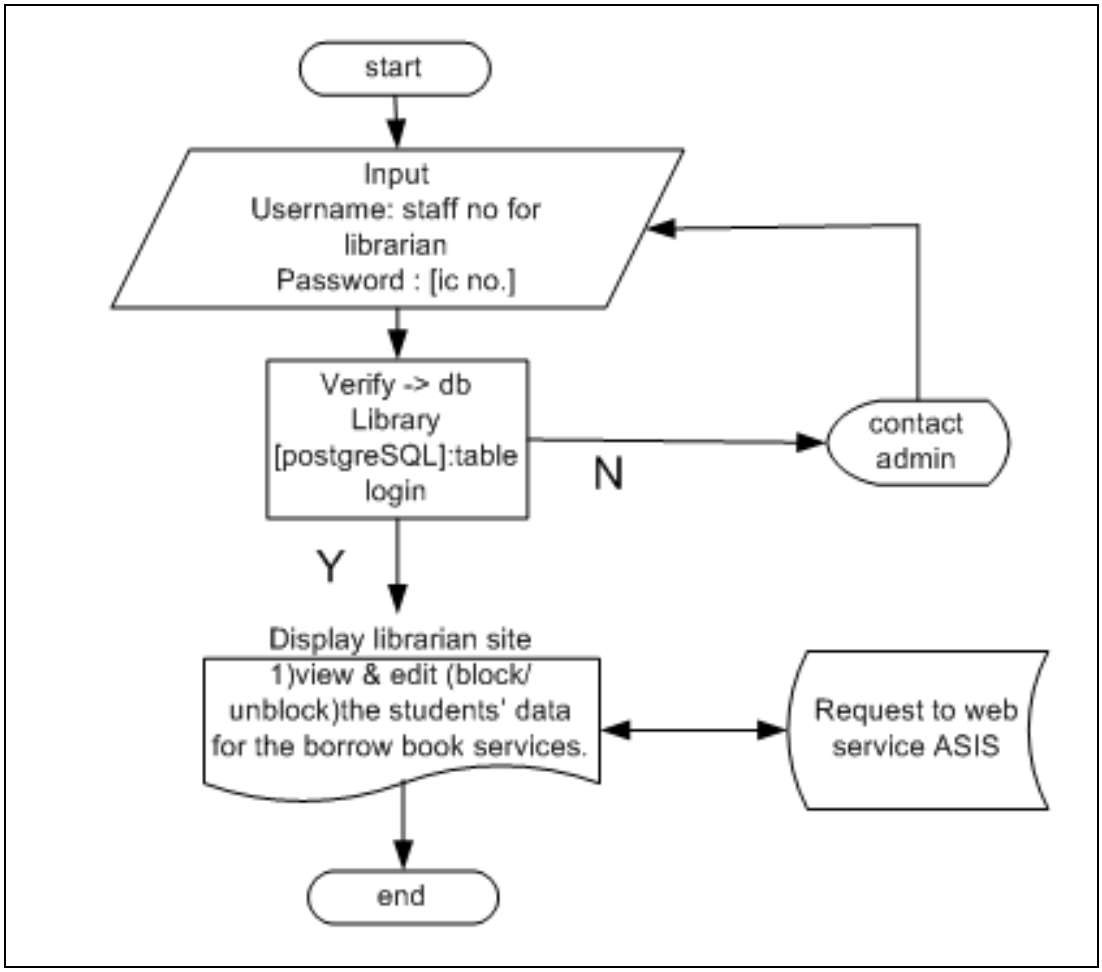

Figure 5.8. Flow chart of LZS Main Functions

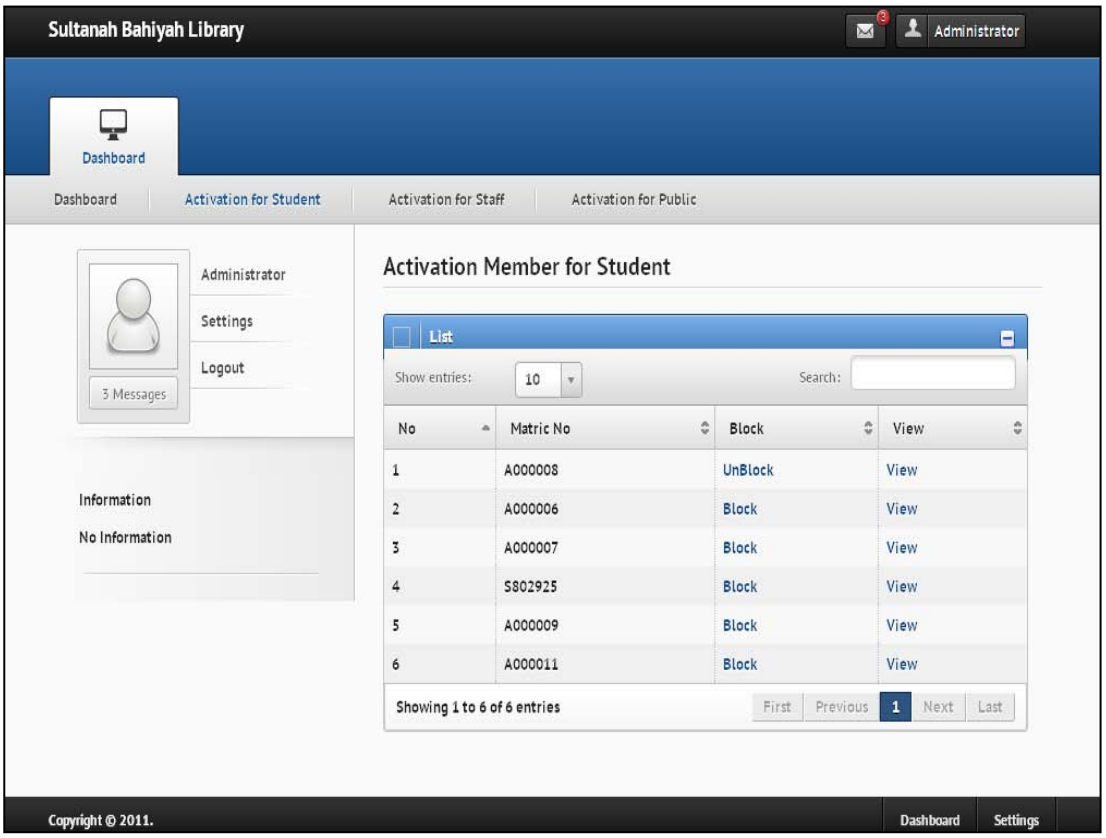

Figure 5.9. List of Library Members' Page

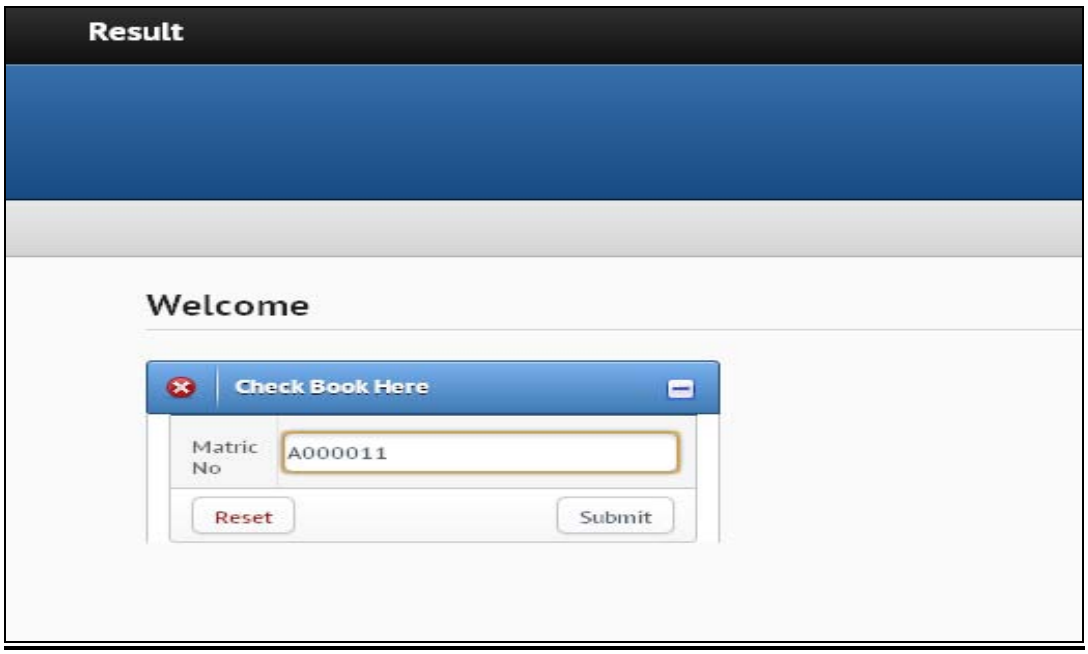

Figure 5.10. Checking Status Student Directly to ASIS for Borrowing Books Permission

5.2.4 Result of Users Evaluation

The evaluation on the prototypes was given to UUM Computer Centre's staff as the users to test (run) the prototypes. They are the persons in charge for the three selected SIS in the case study. Then, based on the testing, the users answered or give their comments in the evaluation form given as attached in the Appendix C. The evaluation result from the average answers of the users is shown in Table 5.2.

Table 5.2

The Average Users' Evaluation Result

Characteristics	**Prototype 1 (ASIS)** Service provider	**Prototype 2 (LZS)** Service consumer 1	**Prototype 3 (Library)** 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, Prototype One (1) performed 100% of all the SOA characteristics, Prototype Two (2) presented 83%, while Prototype Three (3) obtained 71% of the standard characteristics. Overall, the prototypes have achieved the goal of SOA characteristics (as described in Section 2.2.3) with average result 85% of the characteristics achieved, which is means the prototypes are successful implemented as SOA-based system by using the proposed SOA implementation framework. Therefore, these characteristics will be a guide for developing prototypes so that interoperable IS achieved. Then, during the prototypes testing, it was proven all the prototypes could integrated all the needed data across heterogeneous IS in real time. More discussions are presented in the following section.

5.3 Findings

The proposed SOA implementation framework was constructed from a consolidation of existing SOA frameworks and conceptual models. A consensus from four SOA experts had been verified the proposed framework as explained in Section 5.1. The finding of SOA implementation framework for IS integration with heterogeneous programming language and data source types clarify about how to implement SOA approach into heterogeneous IS for integration and leverage more benefits of SOA. With the validated framework, conceptual idea on how to implement SOA becomes a strong validation as it is a good quality for validating conceptual model or framework.

Besides, a case study of heterogeneous IS was conducted in a Malaysia public university, where three heterogeneous SIS were review and had make as a sample to develop three different prototypes with different types of programming language and data sources by using the proposed SOA framework. The prototypes were validated by four experts and four stakeholders as users by testing the functions and evaluated the characteristics of SOA.

Therefore, the findings are relevant to be a guideline for any related developer or organization, who would like to adopt a SOA approach into their IS especially the heterogeneous IS that need to integrate with each other. Based on previous sections of the results presentation, this finding shows that SOA knowledge has been extended and strengthens the idea of developing a quality conceptual framework with empirical validation such as suggested by Moody (2005) and Nelson, Poels, Genero, and Piattini (2011).

5.4 Summary

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

As a result, the SOA implementation has smoothened the SIS business process, as well as helping the person in charge at SIS to use and manage SIS 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 approach in SIS (refer to Section 5.2).

CHAPTER SIX
CONCLUSION

This chapter concludes with a discussion about the SOA requirements to be incorporated into heterogeneous IS integration, the proposed framework 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.

7.1 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 regard to specific objectives.

7.1.1 Research Objective 1

The first objective is to identify the important elements for SOA implementation succeeding in heterogeneous IS integration. This objective is achieved by reviewing works in the previous studies. On top of that, the important elements of SOA have been reviewed for adapting into the heterogeneous IS of the case study. In addition, it is supported by interviews with the SOA experts. Eventually, all the data were analysed, synthesized, and discussed at length in Chapter 2 and Chapter 4. As the conclusion, the most important elements to implement the SOA-based system was XML since it is a supported technology that also used within WS technology. The solution is also consisting of SOAP or HTTP as the protocol transport to bring the

data between service providers, registry and service consumer. Meanwhile ESB is confirmed useful to be employed on a large distributed system integration.

7.1.2 Research Objective 2

The second objective is to construct an SOA implementation framework of consolidation existing frameworks. This is achieved by reviewing the existing SOA conceptual models and frameworks for heterogeneous IS integration especially in the universities environment. Eventually, this study obtained an implementation framework which has been verified by the SOA experts (as discussed in Section 5.1). As a consequence, this study constructed a SOA implementation framework for heterogeneous IS requirements based on experts consensused about the consolidated existing frameworks and adaptation into the case study. The important elements in the framework are WSDL, SOAP, XML, data source, registry, service provider and consumer.

7.1.3 Research Objective 3

The third objective is to validate the proposed SOA framework. The selected three different IS were involved in prototyping experiments in validating the proposed framework. The prototypes were developed with different types of data sources and programming languages and were successfully run. The implementation of prototypes based on SOA was evaluated by users; two application consultants from IT industry, two academicians and four stakeholders of the involved IS in the case study. The users verified that the features and functions built in the three prototypes have followed the appropriate model of SOA basic fundamental, in which there are enough elements as stated in the previous sections of 5.3. Through this validation, it was

proven that the framework is useful in its context (explained in Chapter 5). Hence, it proves that the aim to provide a good design of SOA implementation framework for heterogeneous IS integration is achieved. Thus, it could be a guide to implement SOA successful in integrating heterogeneous IS especially in Malaysia HLI context.

7.2 Limitations and Future Research

The study was limited to only some parts of the selected IS 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 approach in a large distributed IS system which is built using various technologies in heterogeneous IS environment. As a consequence, this study was only able to validate the proposed framework with a small scope of heterogeneous IS. 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:

In this study, the proposed SOA implementation framework was evaluated through the experts review and prototyping tested on some parts of the selected IS from a large distributed system. Accordingly, it is highly to extend the work of evaluating the framework to the whole IS in the university as the case study. The evaluation can be measured more rigorously when all IS involved are able to successfully adopt the SOA approach.

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

7.3 Research Contributions

The proposed framework and related knowledge also can be leveraged among IT professionals in HLI generally in Malaysia and specifically in the case study of UUM systems. The findings and results of this study benefit UUM in terms of providing a guide for incorporating the SOA approach in its heterogeneous IS environment. As a result, the SOA implementation framework could have smoothened business processes of UUM's Students Information Systems (SIS), as well as helping the person in charge at SIS to use and manage the IS effectively and efficiently. On top of that, the problems related to poor interoperability system such as difficulty in automated integrating among the heterogeneous IS in real time could have been solved (as described in Chapter 5).

Therefore, as in the case of UUM, this study has helped the Computer Centre by providing a good SOA implementation framework in creating 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 better services to the university. In detail, the major contributions of this study can be summarized as follows:

The important elements of 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 other researchers and developers to provide the appropriate requirements in implementing SOA into their IS.

The SOA implementation framework has been proposed and validated, then so it is considered accepted as an enhancement of the existing frameworks for IS of the case

study and other related IS. Furthermore, it is accepted as a solution in updating or integrating data easily in real time across heterogeneous IS environment seem it is more interoperability. The solution is also an improvement for SIS architecture because the current IS works with hard coupling seekers and is not able to interoperate in a heterogeneous IS environment.

The SOA implementation framework evaluation was conducted by involving the experts and validated by doing prototyping experiments of the case study. A service can be interacted with via well-defined message exchange. The technology used no longer requires application to interacted with human. This thesis provides SIS Architecture of UUM systems for services interaction. The results of both evaluation and validation techniques are accepted and thus it shows that the SOA implementation framework can be accepted as a guide in implementing SOA into SIS and also other related IS.

7.4 Implication of the Study

The findings in this study could make-up an in-depth understanding about SOA through the implementation framework that has been incorporated into SIS of the heterogeneous interaction. A service can be interacting with via well-defined message exchange. The services concept used no longer require heterogeneous IS integration to interact with human intervention. This study also provides SIS architecture of UUM System for a blueprint IS development. Meanwhile, the proposed SOA implementation framework useful to adopt SOA approach and it has been validated when the development of prototypes run successfully as expected (as explained in

Chapter 5). Therefore, the proposed implementation framework could be a guide for implementing SOA approach into heterogeneous IS integration.

7.5 Summary of the Study

This study considers the incorporation of the SOA approach into SIS, which is used in heterogeneous IS management that needs to automated updates data in real time efficiently. It is important to avoid any repetition tasks and latency time in updating any data. 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 heterogeneous IS and its issues in Chapter 2. The chapter also includes a discussion on the previous IS integration approaches and SOA approach as well. The previous studies that proposed SOA conceptual models and frameworks also highlighted interoperability, which have been revealed that most of domains especially HLI has used SOA approach in a homogeneous environment. The previous studies provide no guidance on how they applied in heterogeneous IS for integration. On the top of that, the factors of succeeding SOA for Malaysia HLI context were discussed, and the SOA validation techniques were also addressed. All requirements and information were analysed in detail. The results of this literature review had given useful information for constructing the SIS implementation framework 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 problems. Further, Chapter 4 discusses the analysis and design works in creating the implementation framework based on SOA. The frameworks used in previous works

are consolidated, and adaptation is made to fit with the SIS requirements. In order to enhance the current architecture of SIS, services layer was added. The interoperability system is achieved with the services layer that consisting WS technology. The proposed implementation framework has been validated after producing better results of prototypes experiments and verification by experts and users (as explained in Chapter 5). The result is proven better than the existing SOA frameworks for heterogeneous IS integration in Malaysia HLI context. All the results and findings were discussed in Chapter 6, which has found that all the methods and experiments were successfully conducted. Moreover, the result of users' evaluation also shows a satisfactory outcome from all the users, including the involved SOA experts.

Overall, this study has delivered its research objectives and provides significant contributions to the conceptual and practical aspects of SOA implementation in the proposed framework. The findings of this study serve as guidance for other researchers as well as to other related organizations for understanding insightful to implement SOA-based system especially involving heterogeneous IS in HLI.

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