SERVICE INTERFACE MEDIATOR MODEL FOR INTEROPERABILITY OF HETEROGENEOUS OPERATION CENTER SYSTEMS

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"Terima kasih yang tidak terhingga di atas sokongan, dorongan dan doa yang diberikan. Kejayaan ini tidak akan bermakna tanpa kalian semua"

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ABSTRACT

In an organization that has heterogeneous system, interoperability is the most important aspect to ensure the information is exchanged effectively. Application developers are usually adopting single Service Interface Design (SID) approach which is not a solution for all situations in Heterogeneous System Integration (HSI) due to its limited integration with System Integration Patterns (SIP). To address the interoperability issues, interfacing processes need to be simplified and formed as a unified service interface at the initial design stage covering SIP on the aspects of File-Based, Common Database, Remote Procedure Call, Socket, Distributed Objects, and Web Services. This study reviewed three prominent approaches related to SID namely Method-Oriented, Message-Oriented and Resource-Oriented. Thus, this study proposed a Service Interface Mediator (SIMed) model comprising the three SID approaches as a centralized Federated Service Interface schema. The model enables two or more types of service interface schema from different SIP to be mapped and matched for the purpose of sharing services among the heterogeneous systems, as such, providing high interoperability for HSI. In addition, Service Interface Signature schema used to validate service interface type during mapping process was also developed based on SID types. A comparative analysis between SID approaches and SIP was carried out to verify how effective both of them can work together. The results showed that the SID approaches were able to interoperate with all types of the SIP. The results were also supported by two types of validation that were carried out to prove the SIMed's capability. First, the interview with industry experts who used to be involved in HSI had given 97.5% score marks; second, the testing of SIMed prototype had reached maximum precision and maximum recall. In conclusion, the proposed SIMed model is able to mitigate the interoperability issues of heterogeneous system.

ABSTRAK

Dalam organisasi yang mempunyai sistem heterogen, saling kendalian merupakan aspek paling penting untuk memastikan maklumat boleh dikongsi dengan berkesan. Pembangun aplikasi biasanya menggunakan pendekatan Rekabentuk Antaramuka Khidmat (SID) tunggal yang bukan merupakan penyelesaian bagi semua situasi dalam Sistem Integrasi Heterogen (HSI) disebabkan integrasi terhad dengan Corak Sistem Integrasi (SIP). Bagi menangani isu saling kendalian, proses antaramuka perlu dipermudahkan dan dibentuk sebagai antaramuka khidmat terseragam pada peringkat reka bentuk awal yang meliputi SIP untuk aspek Fail Data, Pangkalan Data, Panggilan Prosedur Jauh, Soket, Objek Tersebar, dan Perkhidmatan Web. Kajian ini mengkaji tiga pendekatan utama yang berkaitan dengan SID iaitu Berorientasikan-Metod, Berorientasikan-Mesej dan Berorientasikan-Sumber. Oleh itu, kajian ini mencadangkan sebuah model Pengantara Antaramuka Khidmat (SIMed) yang merangkumi tiga pendekatan SID sebagai skema Antarmuka Khidmat Bersekutu terpusat. Model ini membolehkan dua atau lebih jenis skema antaramuka khidmat dari SIP berbeza untuk dipetakan dan dipadankan untuk tujuan berkongsi perkhidmatan di antara sistem heterogen, oleh itu, memberikan saling kendalian yang tinggi bagi HSI. Di samping itu, Skema Tanda Antaramuka Khidmat digunakan untuk mengesahkan jenis antaramuka khidmat semasa proses pemetaan juga dibangunkan berdasarkan jenis SID. Analisis perbandingan antara pendekatan SID dan SIP dijalankan untuk mengesahkan sejauh mana keberkesanan kedua-duanya boleh bekerjasama. Hasil kajian menunjukkan bahawa pendekatan SID boleh berinteraksi dengan semua jenis SIP. Hasilnya juga disokong oleh dua jenis pengesahan yang dijalankan bagi membuktikan keupayaan SIMed. Pertama, wawancara dengan pakar industri yang pernah terlibat dalam HSI telah memberi markah 97.5%; kedua, ujian prototip SIMed telah mencapai ketepatan maksimum dan penarikan maksimum. Kesimpulannya, model SIMed yang dicadangkan boleh mengurangkan masalah saling kendalian bagi sistem heterogen.

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AASHTO	-	State Highway and Transportation Officials
AIDS	-	Automated Incident Detection System
AKLEH	-	Ampang – Kuala Lumpur Elevated Highway Facilities
ATIS	-	Advanced Traveller Information System
ATMS	-	Advanced Traffic Management System
AVLS	-	Automatic Vehicle Location System
BPEL	-	Business Process Execution Language
CCTV	-	Closed Circuit Television
ELITE	-	Expressway Lingkaran Tengah SdnBhd
ETS	-	Emergency Telephone System
FA	-	Field Application
FAUser	-	Field Application User
FSI	-	Federated ServiceInterface
HSI	-	Heterogeneous System Integration
ICT	-	Information, Technology & Communication
IR	-	Interface Registry
ISM	-	Interface Schema Mapper
ITAC	-	Intelligent Traffic Automation Centre
ITACA	-	Innovation Technologies and Applications for Coastal Archaeological
ITIS	-	Integrated Transport Information System
LDP	-	Lebuhraya Damasara Puchong
MA	-	Main Application
MAUser	-	Main Application User
MOM	-	Message Oriented Middleware
MsO	-	Message-oriented Interface

MtO	-	Method-oriented Interface
NTCIP	-	National Transportation Communications for ITS Protocol
OC	-	Operation Centre (OC)
OOP	-	Object-Oriented Programming
PLUS	-	Public Link Utara Se RDBMS latan
RCC	-	Remote Control Center
RDBMS	-	Relational database management system
RPC	-	Remote Procedure Call
RS	-	Remote Server
RsO	-	Resoucre-oriented Interface
SDLC	-	System Development Life Cycle
SCATS	-	Sydney Coordinated Adaptive Traffic System sites
SE	-	Software Engineering
SID	-	Service Interface Design
SIMed	-	Services Interface Mediator
SIMedDB	-	SIMed Database
SIS	-	Service Interface Signature
SOA	-	Service Oriented Architecture
SOAP	-	Simple Object Access Protocol
TCC	-	Traffic Control Center
TMC1	-	Traffic Management Center
TMC2	-	Transport Management Center
UDDI	-	Universal Description, Discovery and Integration
UML	-	Unified Modelling Language
URI	-	Uniform Resource Identifier
URL	-	Unified Resource Locators
VMS	-	Variable Message Signs
WS	-	Web Service
WSDL	-	Web Services Description Language
XML	-	Extensible Markup Language

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CHAPTER 1

INTRODUCTION

1.1 Overview

This thesis describes about the issues and problems as well as a proposed solution model for interfacing that relates to *heterogeneous system integration* (HSI). In an organization having heterogeneous system, interoperability is the most important thing to ensure the data or information sharing among the systems occurs.

Over the years, system integration (SI) has become more complex and more *heterogeneous* due to rapid innovation in the IT industry. The complexity increases when the number of systems involved increased. Systems need to share information by sharing data and functionality of systems involved but it comes from manufacturer or developer that tended to not interoperate (Roshen, 2009). Impacts from this situation, information are unable to exchange effectively and this leads to the *interoperability* problem in SI (Hohpe & Woolf, 2011; Masethe, Adewumi, & Masethe, 2016).

Indeed, the success of interactions among the systems depends on how well the service interfaces are exposed (Teo & Kadir, 2009). The stability of the service interfaces in solving the SI problem has been the subject of many researchers such as in (Larsson, 2007; Djavanshir & Khorramshahgol, 2007; Nilsson, Nordhagen, & Oftedal, 1990). The importance of service interfaces in integration process makes use of this study to focus on the *interoperability*, in addition to identifying the

heterogeneity as well as *uniformity* and *compatibility* of the service interfaces involved.

To address the HSI interoperability issues, interfacing processes need to be made more easily by defining components, subsystems, processes, and interfaces that affect the SI architecture at the initial design stage.

Architectural design is the stage where the process of identifying the interfaces involved in SI is to be considered. The interface architecture that serves as *mediator* or intermediaries to provide access to specific functions or services for heterogeneous systems is central to this study.

1.2 Background of the study

Preliminary review on the system interoperability in Malaysian public sector found that the majority of studies were about the integration of systems were involving organizations with Operation Center (OC) (Hashim, 2006; Kassim, 2006; Masbah & Abidin, 2006). An organization with an OC especially in the public sector, is still struggling with integration challenges due to interoperability issues. An OC requires heterogeneous and centralized integration for data collection, processing and dissemination of information.

Based on these preliminary review findings, a case study was conducted in order to get clear picture on the OC systems architecture. A small-scale of exploratory study was carried out prior to research project started (Streb, 2010; Per Runeson, Host, Rainer, & Regnell, 2012; Tobi, 2016). This was to confirm a hypothetical scenario which was developed from the findings on the interoperability issues of heterogeneous OC systems.

A high level view of typical OC architecture depicted in the Figure 1.1 is a compilation based on observation made on the selected OCs' operations and the information gathered from informal interviews.

The interviews were conducted on a several OCs' operators, ICT personnel as well as ICT consultants involved in the OCs' SI. Please refer to Appendix B for the questionnaire used as the checklist for the guided interviews and observation activities respectively. The research findings on these activities are discussed in Chapter 5.

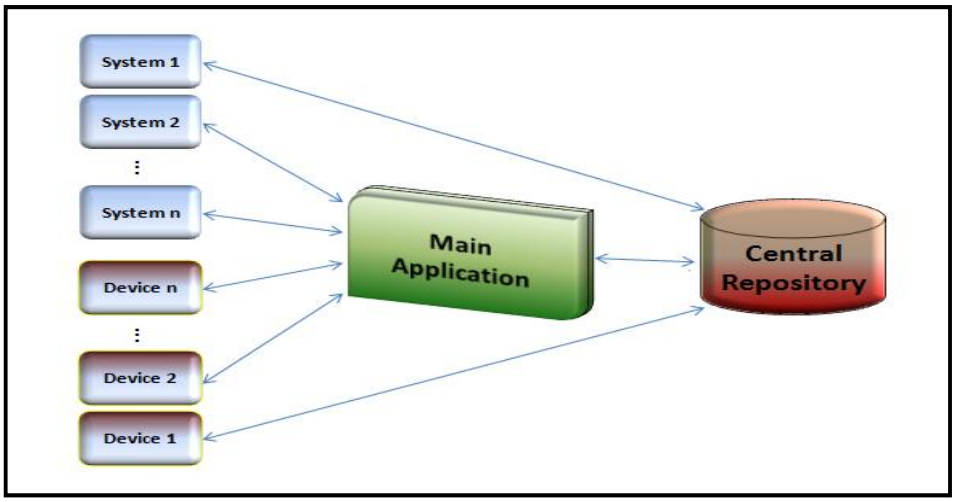

Figure 1.1 High Level Architecture of Heterogeneous OC Systems

Generally, an OC comprise of a main application used by operators, central database for data repository, and monitoring devices such as CCTV and VMS as input to the main application. The main application acted as human interface as well as system interface to other subsystems (Hashim, 2006). OC meets the requirement of this study on SI of heterogeneous systems**.**

i. Problems of the architecture related to Heterogenous Systems in OC

According to Hashim (2006), most OCs are operated separately where information is restricted by the organization itself and no information exchange takes place between the operating centers. He also pointed out that there should be an integration mechanism that becomes an industry standard that could be used by the OC of an organization. This is to ensure future SI can be implemented without being limited by a technology.

As the number of integrated systems doubled, the number of interfaces linking to the main systems increased and the interface type became various. The *interoperability* and *compatibility* of multi-interfacing became an integration issue to be solved. Accordingly, the management of interfaces became a big challenge (Hashim, 2006; 2006; Sedek, Omar, & Sulaiman, 2015). One of the possible solutions is to have *uniformity* and *compatibility* interfaces for solving the *interoperability* among the systems. The *heterogeneity* interface has been included as a part of the solution in this research.

ii. The needs for Service Interface Mediator

From the background of the problem described previously, it is shown that there is a need for the uniformity and compatibility of interfaces in the heterogeneous OC systems integration in order to address the interoperability problem. A study must be conducted so that most if not all OCs can use the same common interfaces which can increase the effectiveness of OC system integration.

Another problem of heterogeneous OC systems integration that need to be looked into is the architecture of an interface serving as mediator to provide access to certain functions or service in a system of an OC. Mediator approaches have been chosen by few researchers since early 90's (Wiederhold, 1992; Papakonstantinou et al., 1995; Panchapagesan et al., 1997; Fowler et al., 1997). The service interface mediator (SIMed) is required due to heterogeneity of SI in an OC.

Service interface is an important element for interaction in SI. Several studies stressed out that the successful of interactions among the system is depending on how well you exposed the service interfaces (Henkel & Zdrakovic, 2005; Teo & Kadir, 2006). Well-designed SI architecture should be able to be extended with relative ease to accommodate new applications without requiring extensive infrastructure development with regards to the needs of simplifying SI process.

The problems arise when there were large differences of how the service interfaces were being declared and used to invoke a service. Service architectural base has become a style used that allows interaction of diverse applications regardless of their platform, implementation languages and locations by providing a service. The interactions are highly depending on how service interfaces are exposed (Teo & Kadir, 2009).

In this case, Service Interface Mediator (SIMed) model has been proposed as a solution to accommodate the service sharing in the SI design. Service Oriented Architecture (SOA) and Web Services have been chosen as method for the design of the model.

Three prominent approaches related to Service Interface Design (SID) had been reviewed and mentioned in this study which was *method-oriented, message-oriented* and *resource-oriented*. Service interface is an important element of interaction in SI, thus, the proper design of the services is also important. Thus, the needs of SIMed model become a vital point in this situation.

1.3 Statement of the Problem

Previous subsections have discussed potential issues to be carried as research issues on the interoperability problem in the heterogeneous OC systems integration. The lacks of interoperability leads to information are unable to exchange effectively (Roshen, 2009; Hohpe & Woolf, 2011; Masethe et al., 2016).

In traditional SI, application developers are more familiar with single SID approach that able to integrate with limited integration pattern or systems. In such case, the integration design is scoped within the context of single SID approach. For example, method-oriented services can only talk with few System Integration Pattern (SIP) such as file-based (Kazman, 2013) and remote procedure call (Hohpe & Woolf, 2011). It shows the interoperability of method-oriented with SIP is low due to this limitation. Hence, the SI involving SIP demands a service interface mapping mechanism which can mediate the interaction between SID and SIP during the integration process. As discussed previously, mediator approaches concern on providing access to specific functions or services for heterogeneous systems (Wiederhold, 1992; Papakonstantinou et al., 1995; Panchapagesan et al., 1997; Fowler et al., 1997; Bromberg et al., 2011; Inverardi & Tivoli, 2013; Bennaceur et al., 2015)

Therefore, the main research question for this study is *how to improve the interoperability of Heterogeneous System Integration based on Mediator?*

1.4 Research Question

To answer the main research problem, the following research questions have been defined and addressed:-

i. What is the main problem of *Heterogeneous System Integration*?
    a. What is the level of interoperability of the components using SI Design approaches?
    b. What is the level of interoperability of the components using SI Patterns?
ii. How to make the components of SI Design approaches and the components of SI Patterns interoperable effectively?
    a. What kind of mediator to be innovated?
    b. What are the components and mechanism to be used to form up the effective mediator?

iii. How to validate the mediator to ensure it meets the objectives of the HSI interoperability?
   a. What type of approach to be used for evaluation of the mediator?

1.5 Objectives of the Research

The aim of this research is to innovate a mediator model using federated service interface schema to improve the interoperability of *Heterogeneous System Integration.*

In order to achieve the above aims, listed below are the objectives of this research based on the problem statement given:

i. To explore the problems of HSI and analyse the interoperability of components of SID approaches and SI patterns.

ii. To innovate *Service Interface Mediator* (SIMed) Model for improvement of interoperability of HSI.

iii. To validate the effectiveness of the proposed model based on industrial experts' views and system test in a simulated environment.

1.6 Scope of the Research

A model with new approach on service interfaces design for HSI using web service was the end result of this research. As such, the study was focused on the following scope:-

i. Heterogeneous OC Systems Integration

The focus of this research was to improve SI in the scope of Heterogeneous OC system architecture. The term integration in information technology context expressed as a technical concern understood in terms of the physical and logical interconnections of computer-based information systems that communicate and share data (Gulledge, 2006).

To prevent SI from becoming too complex to manage, SI must be well-designed. More explanation on SI and integration patterns can be found in Chapter 2.

ii. Service Interface Design Approach

In order to address the complexity of systems integration it is necessary to determine components of the SI as early at design stage. Integration architectural design is one of the key process areas of SI development (Djavanshir & Khorramshahgol, 2007) and it is emphasized in this study.

Interfacing enables the communication or integration process occurs. An interface is a set of defined operations provided by a server that can be invoked by its clients. Three approaches to SID namely as *method-oriented interfaces, message-oriented interfaces,* and *resource-oriented* interfaces discussed and included in this study.

iii. Web Service Architecture

Web Service (WS) has been used as the architecture reference for the SIMed design in this study. Enabling WS-based SIMed model allows interaction of diverse applications regardless of their platform, implementation languages and locations. The WS includes methodologies and strategies to follow in order to develop

sophisticated applications and information systems. More explanation on the WS can be found in Chapter 2.

iv. Federated Service Interface Schema and Schema Mapping

One of the main characteristics of the SIMed model is to provide Federated Service Interface schema that able to map and match between two or more types of web service interfaces during SI. Schema Mapper has been designed for interface schema matching which is formed part of major component in SIMed architecture.

The Schema Mapper comprises of two components which are Transformer and Converter. Transformer is used to transform interface service(s) into compatible form agreed between integrated systems meanwhile converter is used to do data conversion in order to make it compatible and acceptable to the receiving system. The details of interface schema mapping process are described in Chapter 4.

1.7 Significance of the Study

To implement SI is not an easy task. The complexity of SI increases and become unmanageable when the number of systems involved increased whether it is a centralized system or decentralized. Therefore, it is necessary to determine the components, subsystems, processes, and interfaces impacting the systems integration architecture during the design phase.

System interfaces standardization initiatives have begun in the past ten years (O'Connor & Hubers, 2002) but mostly involved in the very complex integrated environment such as Healthcare Industry (Schultz, 2004), Transportation Industry, Construction Industry (O'Connor & Hubers, 2002) and so forth. Some standards-making organizations, as well as researchers and vendors have attempted to address the elements of SI and minimize related problems (Eisner, 2002).

As a result, Industry Standards for SI of such area have been established for example Health Level Seven International (HL7) for Healthcare industry (Ghani, Bali, Naguib, Marshall, & Wickramasinghe, 2008) and National Transportation Communications for ITS Protocol (NTCIP) standard for Intelligent Transport System (Hashim, 2006). However, there is no framework or model being established in Malaysia to support HSI for OCs in public sector. An interface model seems to be really essential as to provide common reference of HSI across OCs in government agencies.

As such, this study will contribute as an attempt to address the problem of interoperability in HSI as well as a first step towards establishment of SIMed Model with regard to organization having an OC.

1.8 Organization of the Thesis

The thesis is organized into seven chapters including this chapter:

Chapter 2: This chapter reviews the existing literature on the related research topic. It starts with the definition of SI and the SI Patterns. Next, it defined Heterogeneous, Interoperability, and Mediator Approach. It continues with explanations on *"what is"* and *"why"* SOA and WS used in this study. Subsequently, the evaluation of three common approaches on SID is presented. Comparative evaluation of the approaches is described based on the chosen criteria. Operation Center, Research Gap, and Summary presented at end of this chapter.

Chapter 3: This chapter describes research procedure, operational framework and instrumentation used to deliver the thesis objectives. Research assumptions and limitation and method for evaluation are also described. This chapter also details up the case study and the evaluation method used in this research.

Chapter 4: This chapter extends the results of findings and analysis from the research gap in Chapter 2. Proposed solution as a result of analysis of previous studies is described with conceptual model and design architecture. SIMed Model as architecture to improve system interoperability in HSI is explained in details.

Chapter 5: This chapter discusses the findings on the case studies conducted. Analysis of operation concept of the OCs, ICT components involved, SI architecture, integration technology used and interfacing approach which were based on research question are explained.

Chapter 6: This chapter covers the validation of SIMed model based on industry experts' judgments and validation of the interoperability of SIMed prototype using Precision and Recall method based on the test scenario. The results of evaluation are described in detail on this chapter.

Chapter 7: This chapter covers conclusion and future works of the conducted research. This chapter is important to give a clear picture about the linkage between thesis goal and result that has been achieved on the thesis and also the limitation that need to be carried out in the future. The future work is presented as well to give an opportunity to other researchers in the future.

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