

TOWARDS EFFECTIVENESS OF INTEGRATION AND INTEROPERABILITY OF ONE-STOP E-GOVERNMENT PORTAL

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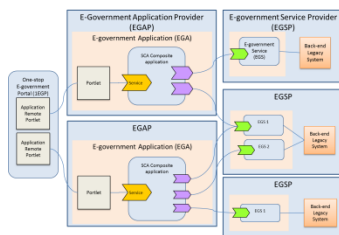
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Graphical abstract



Abstract

An effective one-stop e-government portal requires a system with good integration and interoperability. However, most e-government portals lack in integration and interoperability. This work aims to find an effective approach for e-government integration and interoperability for one-stop e-government portal. This paper presents a hybrid e-government architecture based on architectural principles, enterprise operational interoperability architecture and service component architecture (SCA). The experiment shows the proposed architecture is able to satisfy interoperation in terms of potentiality, compatibility, and performance tests for integration and interoperability e-government applications and services. The architecture is suitable for the development of one-stop e-government portal.

Keywords: Software architecture, one-stop e-government portal, integration, interoperability, service component architecture (SCA)

Abstrak

Satu portal e-kerajaan sehenti yang berkesan memerlukan satu sistem dengan integrasi dan saling boleh kendali yang berkesan. Walau bagaimanapun, kebanyakan portal e-kerajaan kekurangan dalam integrasi dan saling boleh kendali. Kerja ini bertujuan untuk memperolehi seni bina integrasi dan saling boleh kendali e-kerajaan yang berkesan untuk portal kerajaan sehenti. Kertas ini membentangkan senibina hibrid e-kerajaan berdasarkan kepada prinsip-prinsip seni bina dari seni bina antara operasi perusahaan dan kerangka komponen perkhidmatan (SCA). Eksperimen dalam kajian menunjukkan seni bina yang dicadangkan dapat memenuhi potensi saling kerja dalam aspek, kebolehan, keserasian, dan ujian prestasi. Seni bina ini sesuai untuk pembangunan portal e-kerajaan sehenti.

Kata kunci: Senibina perisian, portal e-kerajaan sehenti, integrasi, kebolehan saling-kendali, senibina komponen perkhidmatan (SCA)

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1.0 INTRODUCTION

One-stop e-government concept refers to accessibility of public services in a single platform [1]. An e-government should be capable in providing a one-stop point-of-service as an access channel that conveys a simple and effective image of the concerned government. Users need an effective one-stop e-government portal which provides central access to all government services in a single window [2].

In order to provide a one-stop e-government, some challenges and issues need special attention due to increasing of service complexity. The issues and challenges of a one-stop e-government include:

1. Addressing integration and interoperability issues [3]–[5].
2. Reducing redundancy of services [6].
3. Building trust among departments and agencies as service providers [7].
4. Choosing enterprise architecture that can be adopted by e-government projects [8]

Indeed integration and interoperability are the main obstacles to provide an effective one-stop e-government portal. Two challenges in integration and interoperability are implementation to connect heterogeneous government systems and large number of complex systems, which are developed from proprietary development platform, unavailability of standards, and heterogeneous hardware and software [9].

This work proposes enterprise architecture (EA) for integration and interoperability among e-government system components, applications, and services. According to Bellman and Rausch [10], "*Enterprise architectures are 'blueprints' for systematically defining an organization's current (baseline) and/or desired (target) environment.*" EA provides guidelines in integrating the strategic and business process with information, technology, and data system at all levels in an enterprise [11]. Its primary strength can define concepts and instruments to predict and control complex technical systems. Furthermore, due to the nature of e-government where technical and organizational processes involve different organization at different interdependent level and different function, EA program is important for e-government integration and interoperability.

E-government integration defines how e-government involves in interaction with other government agencies, businesses, and citizens. Four e-government formations are government to citizen (G2C), government to government (G2G), government to business (G2B), and government to employee (G2E) [12].

Vernadat [13] defines enterprise interoperability as "*the ability of an enterprise to use information or services provided by one or more other enterprises.*" Specifically, e-government interoperability involves technical capability of a heterogeneous government system to smoothly and effectively work together in a

predefined and agreed-upon fashion [14]. Therefore, integration and interoperability approach should support collaboration of different e-government systems for an effective public service provision.

This paper proposes an enterprise architectural approach for integration and interoperability of e-government applications and services using a hybrid and distributed e-government. The aim is to design an effective one-stop e-government portal. The architecture is designed based on architectural principles from enterprise operational interoperability architecture and service component architecture (SCA).

The research starts with problem identification using systematic literature review [15]. This phase examines current and related work in e-government architecture, architectural principles and e-government requirements. The second phase defines research design and hypothesis. The third phase develops proposed solution based upon the result in the previous phases. This phase defines enterprise architectural for e-government. The fourth phase conducts research validation using prototype development as a case study. The proposed architecture is evaluated in prototype development of e-government consists of one-stop e-government portal, e-government applications, and e-government services. This work assesses the prototype using integration and interoperability assessment [16]. The final phase is analysing and discussing the research result.

The experiment shows that the proposed architecture satisfies integration and interoperability test on interoperation in terms of potentiality, compatibility, and performance tests. The architecture is suitable for the development of one-stop e-government portal. The aim of this paper is to present a hybrid and distributed architecture for e-government that consists of a one-stop e-government portal, e-government application providers, and e-government service providers.

The remainder of this paper is organized as follows. Section 2.0 reports the related work. Section 3.0 describes the proposed methodology. Section 4.0 presents the prototype implementation and the prototype evaluation. Section 5.0 presents the discussion of the results derived from the evaluation. Finally, Section 6.0 presents the conclusion.

2.0 RELATED WORK

The factors of effective one-stop e-government portal can be categorised into front-end and back-end attributes [17]. One of the important factors at the back-end of one-stop e-government portal is improvement of integration and interoperability of e-government services into one-stop e-government portal. This also helps to improve service quality of provided through one-stop e-government portal. Service quality and system quality are factors contributed to user satisfaction of e-government

portal [18]. Assessment of e-government service interoperability consists of interoperability potentiality, compatibility, and performance [19].

There are many approaches to improve e-government integration and interoperability. The integration and interoperability approach can be classified into architectural standards, styles, topologies, and infrastructures. Table 1 in Appendix A summarizes some related works.

The majority of current e-government integration and interoperability use Service Oriented Architecture (SOA) based on Web service technology such as [20]–[22]. SOA is an architectural style for building distributed service-oriented application system that is interoperable across any system platforms [23]. SCA is development and deployment model for SOA [24]. It provides a complete model for the construction, assembly and deployment of composite service application.

Basically, integration approach involves a method for connecting systems in a distributed environment to allow data information to be exchanged with each other. Some examples of integration technologies are Simple Object Access Protocol (SOAP), Java Remote Method Invocation (Java RMI), Common Object Request Broker Architecture (CORBA), and Representational State Transfer (REST). Currently, the most common integration technologies are web service based on SOAP and REST. REST implementation is better than SOAP in terms of performance and simplicity. Besides that, SOAP Web service is better in terms of standardization and support from software providers [25].

Interoperability approach ensures services from different providers can work together to perform a certain business process. Interoperability model defines three interoperability levels: technical, semantic, and organizational interoperability [26]. Criteria and approach for each level of interoperability are different. Table 2 presents the interoperability criteria and approach.

E-government needs both approaches (integration and interoperability) because they serve different purposes. Integration focuses on effective data exchange but interoperability focusses on interoperation of services to create a value-added service. Successful integration does not guarantee interoperability, but interoperability requires correct integration approach [27]. However, very few researchers give attention on both integration and interoperability. Limited works have considered interoperability in their architecture. Research in e-government needs to cope with integration and interoperability obstacles by focusing on at least the following three general directions [14]:

1. Foci and purposes of integration and interoperability.
2. Specific limitations and constraints on e-government nature, characteristics, and interaction methods.

3. Processes and outcomes that make e-government integration and interoperability operations successful or unsuccessful.

Table 2 Criteria and approach of interoperability [26]

Interoperability level	Criteria	Approach
Technical	Systems get physically connected to allow data and messages can be exchange reliably and securely.	Process coordination using BPMN, and BPEL
Semantic	The ability to achieve meaningful exchange and sharing of information	Metadata registries and Ontology
Organizational	The ability of organizations to provide services to each other.	Define coordination and collaboration mechanism for inter-organizational processes.

E-government architectures are classified into centralized, decentralized (distributed), full decentralized, and hybrid [28]. In centralized approach all e-government application is hosts in a single node. This approach is easy to maintain and have no integration issue with other system. However, due to collaboration needs among government agencies this approach will increase burden of centralized e-government to host all e-government application and services. In distributed architecture, system resources are distributed amongst the participating nodes, and no centralized unit is mandatory [2]. This approach has no control by a centralized body to encourage collaboration. All government agencies has burden to develop their own e-government application which need very high development effort, expertise and cost. Therefore, a hybrid approach which combines both centralized and distributed approach is needed. In hybrid approach, components in e-government integration and interoperability can be in centralized or distributed. This approach can segregate development effort, expertise and cost accordingly based on the structure, role and size of organization.

Very few works proposes a hybrid approach for intermediation architecture for cross-organizational systems. The hybrid architecture eases monitoring of workflow instance using agent-based platform and workflow management system [29]. Due to the complex system of public administration in terms of its structure, heterogeneous system, and distributed information sources [9], effective and efficient hybrid architecture is needed. The Indonesian e-government architecture [21] has clear structure

based on national administration structure that consists of national, province, and district/city administration level whereas other works propose e-government portal integration with e-government service providers using SOA, Web service, or ESB. Each service provider can directly become service provider to the e-government portal. The initial Indonesian e-government infrastructure is based on complex full distributed grid service topology [30] and government service bus (GSB) [21]. As comparison, this proposed architecture is not fully distributed. It has centralized one-stop portal and centralized e-government application at ministry level. E-government services are totally distributed to all e-government service providers at government department level.

3.0 INTEGRATION AND INTEROPERABILITY ARCHITECTURE FOR E-GOVERNMENT

This research is based on software engineering science research method [31]. It has seven phases:

1. Problem identification: define problem based on Malaysia e-government and provide the value of integration and interoperability for one-stop e-government portal.
2. Hypothesis creation: provide description of new architectural approach for e-government portal by formulation of one-stop e-government portal requirements and architectural principals.
3. Working method definition: identify research paradigm and method.
4. Solution formulation: design and develop integration and interoperability architecture for one-stop e-government portal.
5. Validation and verification of solution: demonstrate the implementation of architecture in a prototype of Malaysia e-government system which consists of one-stop e-government portal, e-government application providers and e-government service providers. It becomes proof-of-concept prototype to validate the application in design and development of one-stop e-government portal.
6. Result of analysis and conclusion: the prototype is evaluated using integration and interoperability assessment.
7. Report writing: write documentation of research result and discussion.

Malaysian public administration has a federal government, three federal territories (Kuala Lumpur, Labuan, and Putrajaya) and 13 state governments. Figure 1 depicts the organizational chart of Malaysia's public administration. Based on 2013 cabinet line-up, the federal government have 24 ministries. The Public Service Department (PSD) is responsible for human-resource management policy. The Malaysia Administrative Modernisation and Management Planning Unit (MAMPU) is a federal agency under Prime Minister Office Department that is responsible to develop Malaysia E-government

system. The Malaysian e-government site is www.malaysia.gov.my. It is a central portal of Malaysian E-government, which provides links to other e-government services.

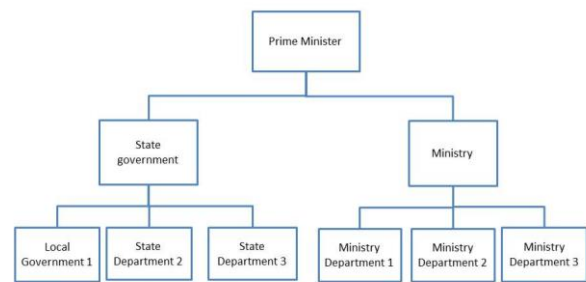


Figure 1 Malaysia administration organizational chart

According to MyGov Statistic for May 2013, as at April 2013 there are 49 online services [32]. The number of external online services is 1,264 and downloadable form is 913. From April 2012 to April 2013, the total number of Malaysian e-government portal is stated as 6,584,966 visits, 191,299 hits to internal online service, and 210,545 hits to the external online services. Four e-government user categories are citizen, permanent resident, non-citizen, and business. Most e-government users are citizen and business users. Malaysia also has a private owned e-government portal called MyEG (www.myeg.com.my). The portal provides online services for nine public agencies that are Road Transport Department, Royal Police of Malaysia, Tenaga Nasional Berhad, Telekom Malaysia Berhad, Jabatan Insolvency Malaysia, National Registration Department, Malaysia Immigration Department, and Pusat Pungutan Zakat. Based on the number of hits, it show that the demands for e-government is quite high. However, Malaysian e-governments still have limited number of online services. Most of the services faces integration problem [33].

This paper proposes an architectural solution for a one-stop e-government. The main strategy in the methodology is to improve the integration and interoperability of an e-government portal with e-government service providers. The fundamentals or elements of system architecture as defined in ISO/IEC 42010 (IEEE Standard 1471-2000) [34] consist of the following items:

1. System elements that constituents make up the system.
2. The relationships of both internal and external to the system.
3. The principles of system design and evolution.

The architecture for one-stop e-government is designed based on the requirement and architectural principles.

3.1 Architectural Principles

Architectural principles are one of the important elements of system architecture. It describes the elements of the system and their function relationship for the integration and interoperability between system elements. The design principles can be derived from practice or reviewing literature [20]. The literature review adopts the systematic literature review (SLR) based on Kitchenham [35]. The architectural principles in this paper are derived from earlier study [36] and architectural requirements.

The architectural requirement is as the following:

1. Effective integration and interoperability of government service network.
2. Integration of both traditional and online delivery channel.
3. Support process interoperability in e-government application and service.
4. Loosely-coupled integration of one-stop e-government portal, e-government application providers, e-government services providers and other shared e-government services.
5. Interoperability of e-government applications and e-government services.

Architectural principle is adapted from architectural principles by Gong and Janssen [20]. Based on the architectural requirement above, this work proposes architectural principles as the following:

1. Develop an organization of e-government applications and services according to government administration structure.
2. Create an e-government application from the components of e-government services (EGS).
3. Separate government rules (GR) derived from a policy from operational concerns.

3.2 Architecture Component and Relationship

The e-government architecture is aimed to improve integration and interoperability among e-government systems and services using hybrid and distributed architecture. Users access e-government services through a centralized one-stop e-government portal. The distributed e-government applications and services provide a single access point of e-government applications. It supports interoperability among e-government services to allow effective service sharing and reuse.

The components relationship of an e-government is described in organizational structure. Figure 2 depicts the conceptual architecture of three main components of e-government architecture in organizational structure.

The structure is organized in accordance to national administration structure, which consists of ministries, states and government agencies under ministries and state governments. The main components are one-stop e-government portal (1EGP), e-government application providers (EGAP),

and e-government service providers (EGSP). The portlet in 1EGP linked (shows as free line between portlet and EGA) to EGA in EGAP. EGA is linked (shows as free line between EGA and EGS) to EGS in EGSP.

This structure provides clear roles and responsibilities of each e-government component. This approach should reduce service redundancy and improve service reuse and sharing.

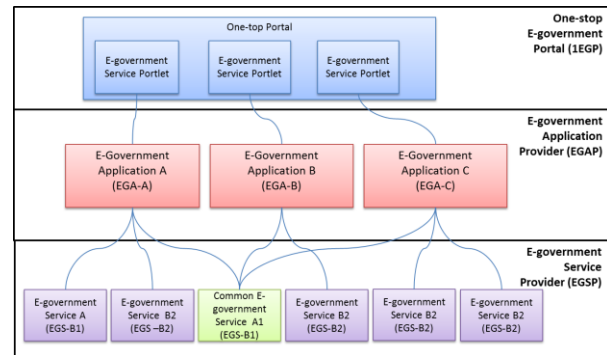


Figure 2 Three-layer e-government conceptual architecture

This work derives distributed e-government architecture based on the conceptual architecture as defined above. Figure 3 depicts the overall hybrid e-government architecture using SCA Assembly Model. SCA Assembly Model is specification to describe SCA application design as example in Figure 4 [37]. IEGP is centralized portal which hosts all e-government application (EGA) to be accessed by e-government users. EGAP provides EGA to 1EGP. EGA is distributed application provided across EGAP. A ministry centralized all EGA under its responsibility. For example all education application such as school application, examination result, and school information is hosts in Education Ministry. EGAP also responsible to coordinates integration and interoperability of EGSP. EGSP is distributed e-government services.

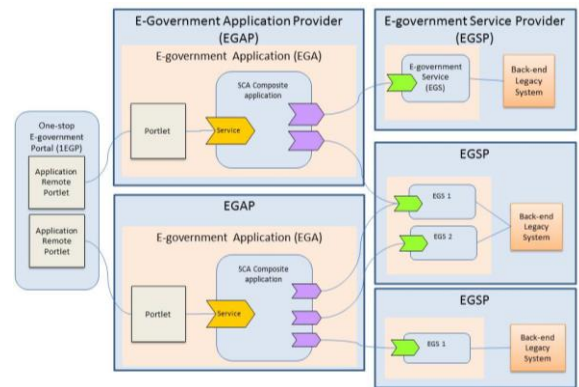


Figure 3 Distributed e-government application and service integration architecture

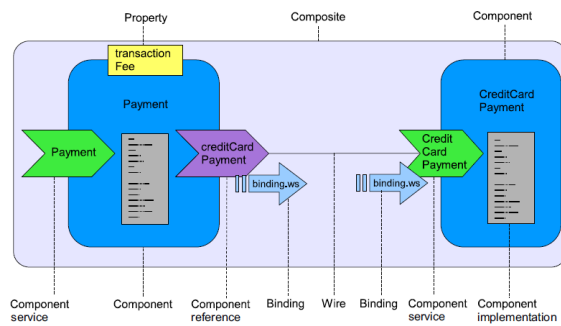


Figure 4 Example of Web shopping application using SCA Assembly Model [37]

EGAP provides EGA to be published in 1EGP. End-users can subscribe EGA according to their need. EGA consists of a portlet as the view layer of EGA and composite application as the application implementation layer. The composite application is responsible to interoperate with e-government service (EGS). EGS is e-government service, which provides supporting service for EGA such as MyIdentity service, examination result service, and student profile service.

3.3 One-stop E-government Portal

1EGP provides a centralized access point for all e-government applications to end-users. The portal is responsible to manage user security and registration, application subscription, and application hosting. The portal needs to integrate with EGAP because EGAP develops and provides the application to be accessed from 1EGP. From the end-user's view, the application is provided from a single system. The application is a result from the integration and interoperability of 1EGP, EGAP, EGSP in many remote systems. Government employees do not have to maintain many front-end systems because 1EGP provides the end-users interface. Government employees of EGAP can use and maintain the existing system.

3.4 E-government Application Provider

The e-government application layer describes the functionality of EGAP. Figure 5 depicts the EGAP architecture. It shows how EGAP integrates with 1EGP and EGSP. EGAP is responsible to develop and provide e-government application (EGA) for 1EGP. It provides distributed application to 1EGP and also centralized all application under its responsibility under a ministry. For example, Education ministry level provides education EGA. EGA is complete portlet application. It is ready to be plugged-in into the 1EGP. EGAP can have multiple EGA as many as needed. The maximum number of EGA in an EGAP is depending on the capacity of the EGAP server.

The main roles of EGAP are:

1. Develop, maintain, and publish complete e-government applications for 1EGP.

2. Develop e-government applications from composition of services.
3. Ensure integration and interoperability between 1EGP and EGSP.
4. Secure the privacy and integrity of applications and information.

The application implementation has five implementation phases: submission and registration, information gathering, filtering, decision making, and notification and issuing phase. The phases ensure effective technical, semantic and process interoperability in application implementation. It is based on enterprise operational interoperability architecture [20].

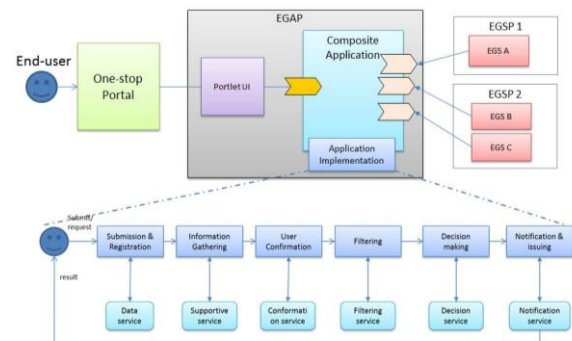


Figure 5 E-government application provider architecture for application and service interoperability

The submission and registration phase saves information from end-user input to the application database. Then, the information-gathering phase obtains the required information from EGSP. For example, this phase retrieves citizen profile detail using supplied user id from the end-users as the process input. The information is provided from different parties from different system. The data format might be different and will cause incompatibility of data. This issue can be handled using automatic data transformation. Tuscany SCA databinding framework can be used to automate data transformation from different format [37].

This eases the government employees to get the accurate information because the EGA obtains the information automatically from EGSP. The information from EGS can be used for the filtering and decision-making in the following phase. The filtering phase has an automatic rule to select sort-listed users for decision-making phase. The decision making phase involves internal users who make a decision to approve or reject the application from the end-user. This phase reduces the employee workload because they only need to make a decision for the selected application only. The result of the application is sent to the respective end-user in the notification phase through notification service. The notification service is responsible to send the notification information to the end-user through email and portal notification. This approach benefits both main stakeholders involved: end-users and internal users (decision

maker). End-users do not have to provide all documentation requirements to submit any service request. The decision maker can make correct decision because the required information for decision making is accurate and trusted. Furthermore, many steps in the application processing have been automated and the information accuracy is achieved through easy, fast, and accurate decision-making.

3.5 E-government Service Provider

EGSP is responsible to implement and manage e-government services (EGS). EGSP provides EGS for EGAP. EGS is full distributed Web service that integrates with the existing the legacy system in the EGSP.

Figure 6 depicts EGS integration with legacy system. It shows two example scenarios. In the first scenario, EGS provides service from existing business logic of legacy Web application in layered architecture. In the second scenario, EGS provides service from controller component of legacy application in MVC architecture. Government agencies at the departmental level are responsible to manage and develop EGA. One EGSP can have many EGS.

Service component granularity can be designed to fine-grained to course-grained component. Fine-grained component has less number of messages than coarse-grained component. Thus, fine-grained component ensure maximum service reuse [38]. Therefore, EGS is fine-grained service to ease EGAP to create coarse-grained component. This reduces the burden of EGSP in development and maintenance of EGS. Furthermore, this approach is more suitable because normally, the departmental level has less development and maintenance resources than those at the ministerial level. Therefore, the burden of development and maintenance is segregated fairly between EGAP and EGSP.

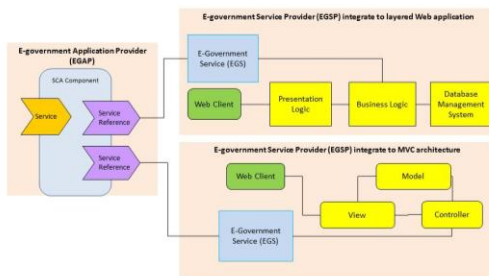


Figure 6 EGSP integration with legacy system

4.0 EXPERIMENTAL PROTOTYPE AND ASSESSMENT

The main goal of prototyping is to test the architecture in terms of integration and interoperability level through the implementation of the architecture in development of the e-government system.

This work follows the following steps:

1. Design the e-government application.
2. Design and develop e-government services.
3. Develop e-government application.
4. Publish e-government application as portlet.
5. Integrate the portlet with IEGP using remote portlet.
6. Test the e-government application and services.

4.1 Case Study Prototype

The prototype simulates the implementation of Malaysian One-stop E-government Portal (MyOneEG). MyOneEG is the one-stop e-government portal that provides e-government services from various agencies in a single access point. The users should be able to access any e-government service without the need to access another portal or e-government system. Figure 7 depicts the end-to-end e-government architecture implementation of the e-government school application. It shows the flow of the service requests from user through the application portlet in the portal. The portal sends the request to EGA. Then the EGA processes the request, which goes through five phases of service implementation in the composite application as described in the Section 3.4. The composite application is responsible to process the request, including interoperability with external EGS to obtain service.

The MyOneEG is implemented using Liferay, an open source portal, web publishing, content, social and collaboration enterprise solutions [39]. The Liferay portal is a portal server and portlet container. The portal provides content as portlets application. The portlet is a complete Java application based on JSR 168 [40] and JSR 286 [41] standards. In this architecture, the portlet can be internal portlet and remote portlet. Internal portlet is portlet hosted in the portal server. Remote portlet is portlet provided by portlet provider and hosted in another portal server. This paper proposes this concept to integrate IEGP and EGAP. The integration uses Web Service for Remote Portlet (WSRP) standard produces by OASIS. The current Liferay version supports both WSRP 1.0 and WSRP 2.0 specification.

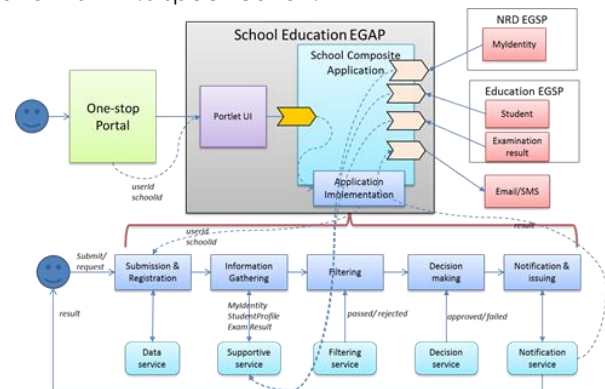


Figure 7 Integration and interoperability architecture for school application e-government service implementation

4.2 Integration and Interoperability Assessment

The proposed work uses interoperability assessment based on the earlier work by Elmir and Bounabat [16]. Three characteristics of the assessment are interoperation potentiality, interoperation compatibility, and interoperation performance. The evaluation processes include the following assessment steps:

1. Delineating the scope of the study.
2. Quantifying the interoperation potentiality.
3. Calculating the compatibility degree.
4. Evaluating the operating performance.
5. Aggregating the degree of interoperability.

4.3 Interoperability Potentiality

Interoperability potentiality measures interoperability maturity model level (IMML) within the k^{th} department <<IP_k>>. E-government IMML evaluation is based on the existing works [42] [26]. Table 3 defines the e-government IMML and the characteristics of each level. The IMML is the combination of enterprise interoperability and e-government interoperability. The enterprise interoperability focuses on interoperability among department or business unit within a business company. E-government interoperability is based on the scope of e-government. Interoperability at the national e-government level involves interoperability among department agencies across the national administration level, including ministerial, departmental and state level.

This work evaluates the interoperation potentiality (IP) on e-government applications and services. Table 4 lists EGA and EGS involved in interoperability potentiality test.

Table 3 Quantification of the interoperability maturity

	E-government IMML	Potential Quantification (0.25 * IMML)
Technical	1	0.25
Semantic	2	0.5
Process	3	0.8
Organizational	4	1

Table 4 List of EGA and EGS

EGA	EGS
School application (EGA ₁)	Student Service (EGS ₁₁) School Service (EGS ₁₂)
Examination application (EGA ₂)	Examination service (EGS ₂₁)
MyIdentity application (EGA ₃)	MyIdentity Service (EGS ₃₁)

Each application has interoperability with EGA and EGS. For example, IP1 has interoperability with School application (EGA1), Student Profile Service (EGS11), Examination Result Service (EGS12), and MyIdentity Service (EGS21). The IP value of IP1 is 0.8. The min of IP of all three EGA is 0.8.

$$\begin{aligned}
 IP &= \min (IP_1, IP_2, IP_3) && \text{(Eq. 1)} \\
 IP_1 &= \text{School Application} \\
 &= (EGA_1, EGS_{11}, EGS_{12}, EGS_{21}) \\
 &= 0.8 \\
 IP_2 &= \text{MyIdentity Application} \\
 &= (EGA_3, EGS_{31}) \\
 &= 0.8 \\
 IP_3 &= \text{MyExamination} \\
 &= (EGA_2, EGS_{21}, EGS_{31}) \\
 &= 0.8 \\
 IP &= \min (IP_1, IP_2, IP_3) \\
 &= \min(0.8, 0.8, 0.8) \\
 IP &= 0.8
 \end{aligned}$$

The test result shows that the e-government system has achieved process interoperability potentiality level.

4.4 Interoperability Compatibility Degree

Interoperability compatibility measures the existence interoperability barriers between collaborated parties [43]. It defines four interoperability concerns and three interoperability barriers. Four interoperability concerns are businesses, processes, services, and data. Three interoperability barriers are conceptual, organizational, and technology. Table 5 shows the elementary degree of interoperation compatibility <<dc_{ij}>>. The evaluation is assigned value 1 to dc_{ij} if interoperability is satisfied and value 0 to dc_{ij} if it is not fully satisfied. For example, there is no satisfied interoperability for business interoperability in syntactic interoperability barrier. However, the process interoperability in syntactic barriers is satisfied. Table 6 shows the result of interoperability compatibility evaluation.

Table 5 Interoperability compatibility matrix

	Interoperability barriers					
	Conceptual		Organizational		Technology	
	Syntactic	Semantic	Authority responsibilities	Organization	Platform	Communication
Business	dc ₁₁	dc ₁₂	dc ₁₃	dc ₁₄	dc ₁₅	dc ₁₆
Process	dc ₂₂	dc ₂₂	dc ₂₃	dc ₂₄	dc ₂₅	dc ₂₆
Service	dc ₃₃	dc ₃₂	dc ₃₃	dc ₃₄	dc ₃₅	dc ₃₆
Data	dc ₄₄	dc ₄₂	dc ₄₃	dc ₄₄	dc ₄₅	dc ₄₆

Table 6 Interoperability compatibility barrier evaluation result

	Interoperability barriers					
	Conceptual		Organizational		Technology	
	Syntactic	Semantic	Authority responsibilities	Organization	Platform	Communication
Business	0	0	1	1	1	1
Process	1	0	1	1	1	1
Service	1	0	1	1	1	1
Data	1	0	1	1	1	1

The degree of compatibility <<DC>> is given as follows:

$$DC = \sum dc_{ij} / 24 \tag{Eq. 2}$$

$$DC = \frac{19}{24} = 0.79$$

The test result shows that the e-government system has satisfied in the interoperability compatibility test.

4.5 Availability Performance Test

This work uses Apache JMeter to measure availability rate of one-stop e-government portal to provide e-government application to end-users. Apache JMeter is a performance testing tool for Web application [44]. It simulates a heavy concurrent load on Web-based application. Table 7 presents the result of the one-stop e-government performance test.

Table 7 Availability performance test

Parameters			Results			
# of threads	Ramp-up	Loop count	Throughput requests/ min	Average	Median (ms)	Error (%)
5	10	50	5.8	1943	2443	0
50	10	50	5.6	2237	2513	0
100	10	50	9.4	3738	4636	0

The test simulates the submission of school application in three different numbers of concurrent users: 5, 50, and 100 users. The results show that when the numbers of concurrent users increase, system throughput becomes faster and still maintains 0% error rate. This shows that the availability performance (PO) is 1.

The test result shows that the integration and interoperability of e-government applications and services has good availability performance and have no error.

4.6 Aggregating the degree of interoperability

The degree of interoperability is measured by aggregating the three interoperability indicators as the following calculation:

$$Ratlop = f(PI, DC, PO) \tag{Eq. 3}$$

The degree of interoperability value is equal to 1 if it is fully satisfied and 0 if it is fully unsatisfied.

$$Ratlop = (PI, DC, PO) / 3$$

$$Ratlop = (0.8 + 0.79 + 1) / 3 \tag{Eq.4}$$

$$Ratlop = 0.86$$

The degree of interoperability is equal to 0.86 which is very to near to 1. This result shows that the degree of interoperability is satisfied.

5.0 DISCUSSION

This work presents hybrid architecture for e-government integration and interoperability. As a result, the architecture helps to improve one-stop e-government portal effectiveness. The proposed hybrid architecture comprises a centralized one-stop e-government portal (IEGP), distributed e-government application provider (EGAP), and distributed e-government service providers (EGSP). IEGP centralizes all e-government applications in a single place so that portal users can access all online services in the portal. The EGAP is responsible to provide e-government application (EGA) to be hosted in IEGP. EGA is distributed application provided at the level of a ministry. Therefore, there are 24 EGAPs if all 24 ministries in Malaysia participate as EGAP. Furthermore, EGA is a centralization of EGS in a ministry that is provided by respective departments under the ministry. For example, Education Ministry EGAP centralizes all education-related applications under it hosting server. EGA is built from composition of distributed e-government services (EGS) while EGSP is responsible to provide EGS for EGAP.

The architectural principles and operational interoperability architecture is adapted from Gong and Janssen [20] to suite the e-government integration and interoperability requirements. Gong and Janssen [20] approach is chosen because it has the fundamentals or elements of system architecture as defined in ISO/IEC 42010 (IEEE Std 1471-2000) [34]. Based on derived e-government architectural principles, e-government operational interoperability architecture is developed. The main purpose is to ensure interoperability between EGA and EGS. The

architecture is implemented in the business rules implementation of SCA application of EGA.

Table 6 in Appendix B shows the comparison evaluation between Indonesian proposed e-government architecture [21] and the proposed architecture in this paper. The Indonesian architecture is the nearest approach with this work as it has organizational structure of e-government service but in different political structure. Malaysia is federal constitutional monarchy consists of thirteen states and three federal territories. In contrast, Indonesia is a republic country with presidential. There is political structure may affect the control of e-government services. This work proposed a hierarchical e-government service structure to ease coordination of integration and interoperability of EGAP and EGSP provided by ministry, department, state, and local government. This work uses common implementation integration between 1EGP, EGAP, and EGSP. EGAP provides EGAP using JSR-286 portlet application as it is a simple and effective method to integrate application and portal. Interoperability in this architecture involves e-government application and e-government services using Tuscany SCA application. Its advantage includes EGA that can be implemented in Java or BPEL unlike Widodo's architecture [21] that can be implemented in BPEL only. It is easier to develop business logic in BPEL; however Java platform provides more flexibility due to its nature of a multi-purpose programming language.

The interoperability potentiality test shows that the architecture achieves process interoperability as presented in Section 4.3 that is anticipated to be sufficient for e-government interoperability in a developing country like Malaysia and Indonesia.

Interoperability compatibility barrier evaluation result achieved satisfied result, 0.79 satisfaction level as shown in Section 4.4. It means that the architecture can overcome interoperability barriers and interoperability concerns effectively.

Based on the availability performance test result as in the Section 4.5, it shows that the prototype has achieved throughputs 9.4 requests per minute and 0% error. Interoperability compatibility barrier evaluation result achieved satisfied result that is 0.79 satisfaction level. It means that the architecture can overcome interoperability barriers and interoperability concerns effectively. The overall result shows 0.86 degree of interoperability that the architecture achieved satisfied integration and interoperability test. However, this work needs further evaluation in a real-world scenario and includes more variety of e-government applications and services.

6.0 CONCLUSION

This work finds effective integration and interoperability for one-stop e-government portal

using hybrid e-government architecture. The hybrid architecture integrates one-stop e-government portal, e-government application providers and e-government service providers based on architectural principles, enterprise operational interoperability architecture and SCA. The architectural principles provide guideline for e-government integration and interoperability architecture. The enterprise operational interoperability provides approach for e-government applications and e-government services interoperability. SCA is used mainly for integration among e-government application providers and e-government service providers.

This paper evaluates the architecture based on a prototype called MyOneEG that simulates an e-government. The integration and interoperability of the prototype is evaluated based upon the interoperability potentiality, interoperability compatibility degree, and availability performance test. Based on the result and discussion of this paper, the proposed architecture promotes the following benefits:

1. Development of effective one-stop e-government portal is supported by effective integration and interoperability of EGAP and EGSP.
2. Simple and effective integration and interoperability hybrid e-government architecture.
3. 1EGP, EGAP, and EGSP have their own function and roles as the entities in the e-government system.
4. The whole of the e-government system (1EGP, EGAP, and EGSP) are more structured and manageable.

The implementation provides an insight on the advantages and disadvantages of the proposed concepts and the chosen design alternatives. It can help future e-government research and development, especially in federal administration structure like Malaysia.

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References

- [1] Verma N. and Mishra A. 2010. India's Approach in Constructing One-Stop Solution Towards E-Government. *Journal of E-Governance*. 33(3): 144-156.

- [2] Dias, G. P. and Rafael, J. A. 2007. A Simple Model and a Distributed Architecture for Realizing One-stop E-Government. *Electronic Commerce Research and Applications*. 6(1): 81-90. Spring.
- [3] Wimmer, M. A. 2002. Integrated Service Modelling for Online One-Stop Government. *Electronic Markets*. 12(3): 149-156.
- [4] Goldkuhl, G. 2008. The Challenges of Interoperability in E-Government: Towards A Conceptual Refinement. In *Proceedings pre-ICIS 2008 SIG eGovernment Workshop*.
- [5] Markande, K. 2011. One-stop Services: A Conceptual Approach Using EA Reference Framework. *SETLabs Briefings*. 9(2): 23.
- [6] Tambouris, E. 2001. An Integrated Platform for Realising Online One-Stop Government: The Egov Project. In *Database and Expert Systems Applications, International Workshop on, Los Alamitos, CA, USA*. 0: 0359.
- [7] United Nations. 2012. United Nations e-government Survey 2012: E-Government for the People-United Nations Department of Economic and Social Affairs. Department of Economic and Social Affairs, United Nations, 2012.
- [8] Ahuja, A. and Ahuja, N. 2008. Why Enterprise Architecture is Must for One-Stop E-Government? In *Emerging Technologies in E-Government*. New Delhi: GIFT Publishing.
- [9] Al-Khanjari, Z., Al-Hosni, N., and Kraiem, N. 2014. Developing A Service Oriented E-Government Architecture Towards Achieving E-Government Interoperability.
- [10] Bellman, B. and Rausch F. 2004. Enterprise Architecture for e-Government. In *Electronic Government*, vol. 3183, R. Traunmüller, Ed. Berlin, Heidelberg: Springer Berlin Heidelberg, 48-56.
- [11] Hjort-Madsen, K. 2006. 2005. Enterprise Architecture Implementation and Management: A Case Study on Interoperability.
- [12] Siau, K. and Long, Y. Synthesizing e-government Stage Models-A Meta-Synthesis Based on Meta-Ethnography Approach. *Industrial Management & Data Systems*. 105(4): 443-458.
- [13] Vernadat, F. B. 2009. Enterprise Integration and Interoperability. *Springer Handbook of Automation*. 1529-1538.
- [14] Scholl, H. J. and Klischewski R. 2007. E-government Integration and Interoperability: Framing the Research Agenda. *International Journal of Public Administration*. 30(8): 889-920.
- [15] Kitchenham, B., Pearl Brereton, O., Budgen, D., Turner, D., Bailey, J., and Linkman, S. 2009. Systematic Literature Reviews in Software Engineering-A Systematic Literature Review. *Information and Software Technology*. 51(1): 7-15.
- [16] Elmir, B. and Bounabat, B. 2012. Integrated Public E-Services Interoperability Assessment. *International Journal of Information Science and Management (IJISM)*. 1-12.
- [17] Maheshwari, B., Kumar, V., Kumar, U., and Sharan, V. 2007. E-government Portal Effectiveness: Managerial Considerations for Design and Development. Presented at the *5th International Congress of e-Governance (ICEG 2007)*, Hyderabad, India. 12.
- [18] Masrek bin M. N. 2007. Measuring Campus Portal Effectiveness and the Contributing Factors. *Campus-Wide Information Systems*. 24(5): 342-354.
- [19] Elmir, B. and Bounabat, B. 2010. E-Service Interoperability Measurement within Business Collaboration Networks. *Proceedings of MICS*.
- [20] Gong, Y. and Janssen, M. 2013. An Interoperable Architecture and Principles for Implementing Strategy and Policy in Operational Processes. *Computers in Industry*.
- [21] Widodo, A. P., Istiyanto, J. E., Wardoyo, R., and Santoso, P. 2013. Framework Based on a Real Time Architecture Time Architecture. *IJCSI International Journal of Computer Science Issues*. 10(1).
- [22] Li, Y., Chen, H., Zheng, X., Tsai, C.-F., Chen, J.-H., and Shah N. 2011. A Service-oriented Travel Portal and Engineering Platform. *Expert Systems with Applications*. 38(2): 1213-1222.
- [23] Xu, D. J., Liao, S. S., and Li, Q. 2008. Combining Empirical Experimentation and Modeling Techniques: A Design Research Approach for Personalized Mobile Advertising Applications. *Decision Support Systems*. 44(3): 710-724.
- [24] Edward, M. 2007. Service Component Architecture (SCA) Specification. OASIS - Open CSA, 2007. [Online]. Available: <http://www.oasis-opencsa.org/sca>.
- [25] Mulligan, G. and Gracanin, D. 2009. A Comparison of SOAP and REST Implementations of a Service Based Interaction Independence Middleware Framework. In *Simulation Conference (WSC), Proceedings of the 2009 Winter*. 1423-1432.
- [26] Novakouski, M. and Lewis, G. A. 2012. *Interoperability in the E-Government Context*. SEI, Carnegie Mellon University.
- [27] Panetto, H. and Molina, A. 2008. Enterprise Integration and Interoperability in Manufacturing Systems: Trends and Issues. *Computers in Industry*. 59(7): 641-646.
- [28] De Angelis, F. 2009. Interoperability in e-Government Services. School of Advanced Studies-Doctorate Course in "Information Science and Complex Systems"(XXI cycle).
- [29] Verginadis, G., Gouvas, P., and Mentzas, G. 2005. An Hybrid Intermediation Architectural Approach for Integrating Cross-Organizational Services. In *On the Move to Meaningful Internet Systems OTM 2005 Workshops*. Meersman R., Tari Z., and Herrero P., Eds. Springer Berlin Heidelberg. 452-460.
- [30] Rachmawati, U. A., Sensuse, D. I., and Suhartanto, H. 2012. Initial Model of Indonesian E-Government Grid Services Topology. *International Journal of Computer Theory and Engineering*. 656-661.
- [31] Marcos, E. 2005. Software Engineering Research Versus Software Development. *ACM SIGSOFT Software Engineering Notes*. 30(4): 1-7.
- [32] MAMPU. 2013. Operations Support Assistance Management Report - Mygov Statistic. Unit Pemodenan Tadbiran Dan Perancangan Pengurusan Malaysia.
- [33] Ramli, R. M. 2012. Hybrid Approach of E-Government on Malaysian E-Government Experience. *International Journal of Social Science and Humanity*. 2(5).
- [34] ISO/IEC, ISO/IEC 42010:2007. 2007. Standard for Systems and Software Engineering-Recommended Practice for Architectural Description of Software-Intensive Systems. New York: ISO/IEC, 2007.
- [35] Kitchenham, B. A. 2007. Guidelines for Performing Systematic Literature Reviews in Software Engineering Version 2.3. Keele University and National ICT Australia Ltd., Joint Technical Report.
- [36] Sedek, K. A., Sulaiman, S., and Omar, M. A. 2011. A Systematic Literature Review of Interoperable Architecture for E-Government Portals. In *Software Engineering (MySEC), 2011 5th Malaysian Conference in*. 82-87.
- [37] Laws, S., Combella, M., Feng, R., Mahbod, H., and Nash, S. 2011. *Tuscany SCA in Action*. Stanford, CT: Manning.
- [38] Erradi, A., Anand, S., and Kulkarni, N. 2006. SOAF: An Architectural Framework for Service Definition and Realization. In *IEEE International Conference on Services Computing, 2006. SCC '06*. 151-158.
- [39] Yuan, J. X. 2012. *Liferay Portal Systems Development*. Birmingham: Packt Publishing.
- [40] Abdelnur, A. and Hepper, S. 2003. JSR 168: Portlet specification. Sun Microsystems and IBM.
- [41] Nicklous, M. and Hepper, S. 2008. JSR 286: Portlet Specification 2.0. Standard Available (retrieved 2011-06-25) at <http://www.jcp.org/en/jsr/detail>.
- [42] Chen, D., Doumeingts, G., and Vernadat, F. 2008. Architectures for Enterprise Integration and Interoperability: Past, Present and Future. *Computers in Industry*. 59(7): 647-659.
- [43] Chen, D., Vallespir, B., and Daclin, N. 2008. An Approach for Enterprise Interoperability Measurement. *Proceedings of MoDISE-EUS*. 1-12.

- [44] Wu, Q. and Wang, Y. 2010. Performance testing and optimization of J2EE-based web applications. In *2010 Second International Workshop on Education Technology and Computer Science (ETCS)*. 2: 681-683.
- [45] Yan, P. and Guo, J. 2010. Researching and Designing the Architecture of E-Government Based on SOA. In *2010 International Conference on E-Business and E-Government (ICEE)*. 512-515.
- [46] Qing, Chen. 2010. Content-oriented E-Government Information Portal Architecture and Strategies. In *2010 International Conference on E-Business and E-Government (ICEE)*. 468-471.
- [47] Zhu D., Li Y., Shi J., Xu Y., and Shen W., "A service-oriented city portal framework and collaborative development platform," *Information Sciences*, vol. 179, no. 15, pp. 2606–2617, Jul. 2009.
- [48] Charalabidis, Y., Lampathaki, F., Sarantis, D., Sourouni, A. M., Mouzakis, S., Gionis, G., Koussouris, S., Ntanos, C., Tsiakaliaris, C., Tountopoulos, V., and others. 2008. The Greek Electronic Government Interoperability Framework: Standards and Infrastructures for One-Stop Service Provision. In *Panhellenic Conference on Informatics*. 66-70.

Appendix A**Table 1** Related work in e-government architecture

Type of System	Integration approach and topology	Interoperability approach	Evaluation result
Enterprise architectural framework for Indonesian e-government [21]	SOA and BPEL	Real-time interoperability using Government Service Bus (GSB) based on BPEL	Simulation implementation in different development platform at the district/city, province, and national level. The simulation is tested by measuring execution performance of service interoperability.
Technical architecture of service-oriented one-stop travel portal [22]	Proposed service engineering platform for integration of centralized one-stop portal travel portal and distributed service providers based on Web service SOA.	Not available	Implementation in development of travel portal for Shanghai World-Expo portal. Benefits: 1. Provide design and modelling tools for complex SOA application. 2. Provide pre-existing templates in the development SOA application to reduced application development and deployment time.
SOA-based e-government [45]	Proposed Government Service Bus (GSB) an ESB based on SOA for distributed heterogeneous environment.	Not available	No available
Content-oriented e-government portal [46]	Content integration approach using Content Management System's (CMS) content duplication integration module.	Not available	Allow secure information sharing for e-government portal using content oriented e-government information portal.
City One-top Portal [47]	Web service SOA to integrate applications, coordinate systems, and aggregate information.	Not available.	Implementation in development start-up concept design for Digital City Portal of Shanghai Yangshan city to integrate intelligent transportation systems and GIS systems show that it helps to provide responsive and powerful services to their residents.
Distributed architecture for one-stop e-government [2]	SOA based SOAP Web service for integration of one-stop e-government and its service providers. Proposed distributed three nodes architecture consists of requesters, providers, and service repositories.	Not available	Implementation of European's Integrated Platform for Realizing On-line One-Stop Government (eGov) that allows cooperation of government services to provide one stop centre for end-users. It also provides light common ground for interconnection of almost any kind of nodes.
Greek Electronic Government Interoperability Framework for one-stop service provision [48]	Integration of models, tools, and repositories to support e-government one-stop service provision.	Standard interoperability framework (eGIF) to provide paper-based specification for standard interoperability among various stakeholders.	Implementation in Greek's public sector e-government interoperability.

Appendix B**Table 8** Comparison between Indonesian E-government Architecture and the proposed architecture

	Proposed work	Indonesian e-government architecture [21]
Service structure	Specific architecture for federal administration structure. Proposed hierarchical e-government service structure consists of national, ministry, state, and department level.	Widodo's architecture service provider structure: national, province and district/city service provider.
Integration approach	Integration between Portal and e-government application provider using JSR-286 portlet. Integration between e-government application provider using Tuscany SCA application integration. EGAP acts as middleware using SCA.	Integration between service providers using Java Business Integration (JBI). Service providers provide services using Web service binding. Using government service bus (GSB) based on BPEL as middleware.
Interoperability approach	Architecture for interoperability between e-government application and e-government services using enterprise operational interoperability architecture.	SOA and EDA to provide real-time service operation. Service orchestration is defines in GSB using BPEL.
Assessment	Implementation of the conceptual architecture in prototype of one-stop e-government portal, e-government applications, and e-government services. Integration and Interoperability Assessment consist of interoperability potentiality, interoperability degree, and availability performance test.	Implementation of the conceptual model in a simulation environment with a number of e-government services at district, province and national level. Performance testing on service execution time by comparing service execution performance with BPEL and without BPEL.