A Critical Investigation into the Information Communication Technology (ICT) Architecture Supporting Virtual Universities

Nasser Albagami, Dr. Jordan Dimitrov, Sameer Nooh
nsrksa@yahoo.com , jordand@dmu.ac.uk , sa.nooh@yahoo.com
De Montfort University

Abstract

A critical investigation into the information communication technology (ICT) architecture supporting virtual universities confirmed that service oriented architecture (SOA) is the ICT architecture supporting virtual universities. The study was motivated by the desire to have an in-depth understanding of the ICT architecture supporting virtual universities after considering an upwards trend in a large number of organizations interacting in real time over real, large geographic distances creating a virtual world.

Using published work, the study established that different technologies and protocols, such as Service Oriented Architecture SOA, Remote Procedure Call RPC, Transport Protocol TP, Simple Object Access Protocol SOAP, Simple Mail Transfer Protocol SMTP and Extensible Markup Language XML , are being used and can be used to support a third generation virtual university. The study established strengths and weaknesses of SOA and virtual universities who offer all services in an integrated way such as e-learning, specialized virtual centres for developmental educational courses, libraries and administrative functions, interactive environments for asynchronous and synchronous communications and collaboration.

Key words: Service Oriented Architecture (SOA); virtual university.

1. Introduction

There have been many studies associated with virtual universities. In the following paragraphs the writer has outlined a few examples. John (1997) conducted a research study entitled 'Virtual Education in Universities: A Technological Imperative' which focused on the emphasis that many universities and colleges placed on distance education as a way of reaching working adults and controlling costs associated with maintaining campus infrastructures. In the same research John (1997) correctly mentioned that the World Wide Web is being used to provide a medium for offering courses to students anywhere in the world. John (1997) presented that potentially there a number of advantages associated with distance education for all concerned. For example, financial savings will occur as a result of reduced costs associated with building resource and the availability of teaching support 24 hours a day, seven days a week provides a very thorough, round the clock support service which will be extremely beneficial to students. However, using evidence from different universities from different parts of the world, including the UK, some authors presented a reasonable, understandable and acceptable argument. They argued that the unchecked use of ICT in education could disadvantage students and society claiming that students who become too dependent on ICT are in danger of their social skills being neglected. This very worrisome concern was also subsequently raised by O'Donoghue (2001).

O'Donoghue et al (2001) concurred with John (1997) and mentioned that as technology is improving and evolving virtually, it is becoming more real than before. They even made a prediction that in the not-too- distant future it will be possible for courses to be completed solely by distance learning and using the internet for education will take the place of the solid buildings where students currently attend lectures at set times and in set rooms. With virtual universities O'Donoghue et al (2001) predicated that the information will be gathered at the student's convenience

and assignments will be handed in via the internet. This prediction in 2013 is being realised by many universities such as De Montfort University where students are accessing assignments and submitting them through the use of Black Board and Turnitin. The blackboard is one of the most effective teaching tools used in many universities which is offers a communication tool which enables both students and lecturers to communicate easily using it. The lecturer begins uploading his /her lecture notes after logging onto the system using his /her unique user name and password. The Turnitin is a provision for students to submit their work and assignments in addition online plagiarism detection, grammar check, grading tools

O'Donoghue et al (2001) raised a powerful and interesting point that the introduction of ICT in education is here to stay and is being seen as a motivating factor which is being driven by the demand of innovation and creativity in teaching methods. In the process the availability and use of ICT by universities is creating a competitive advantage, opening up new markets and diversifying the student base.

On the aspects of challenges, Georgieva et al (2003) critically discussed nine problems which are outlined as follows, without elaboration. They are: accreditation, copyright issues, quality assurance in learning, systematic education and consultations, mechanism for student's examinations and evaluation, content of learning materials and hardware and software requirements. The same research rightfully mentioned that virtual universities deprive students of learning the social and professional skills which they could have gained by interacting with other students and staff. However, Georgieva et al (2003) did not do any further research on the ICT which supports virtual university education, nor address the technical challenges and benefits of virtualising university education.

1.2 Research aims and questions

From the snapshot of the identified study paper above it is reasonable to conclude that there has been little or no research on the subject of ICT architecture supporting virtual universities. Bearing in mind that there have been developments in information communication technology, such as cloud computing, mobile technology, smart phones, tablets and online social websites such as Facebook and twitter; this paper aims to critically investigate the ICT architecture which supports virtual universities by means of answering two research questions. The first question is 'what is the ICT architecture being used to support virtual universities and what are its strength and weakness?' The second question is 'what are the challenges and benefits of virtualising university education?' The paper also proposes recommendations for meeting the challenges.

1.3 Bringing SOA & SOAP together

Web services use Web Service Description Languages (WSDL) which are illustrated in the two diagrams below, as presented by Barry (2003). The diagrams consist of three players, namely: service providers, service consumers and directories. As defined by Barry (2003) 'a service is a function that is well-defined, self-contained and which does not depend on the context or state of other services'. The same authors provided five steps which are involved in providing and consuming a service.

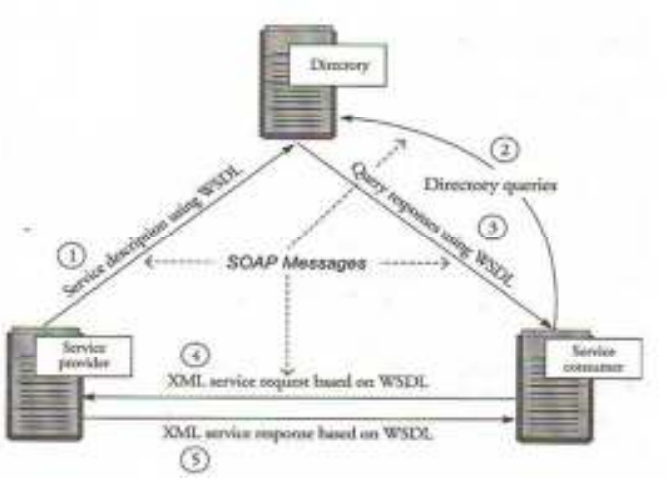

Figure. 1 Basics of Web Services, taken from (Barry, D. K 2003)

Firstly, a service provider describes its services by using WSDL and publishing the definition in a directory of services. The directory uses Universal Description, Discovery and Integration (UDDI). In the second step the service consumer issues one or more queries to the directory to locate a service and determine how to communicate with that service. The third step is when part of the WSDL provided by the service provider is passed to the service consumer and tells the service consumer what the requests and responses are for the service provider. The fourth step is when the service consumer uses the WSDL to send a request to the service provider while the fifth step is when the service provider provides the expected response to the service consumer. All the messages seen on the diagram above are sent using SOAP. SOAP, essentially provides envelopes for sending the web service messages using http or any other means of connection.

2. ICT Architecture being used to support VU

As already mentioned in this paper, the concept of the virtual university refers to a situation whereby higher education programs are provided through electronic media and, in particular, via the Internet. On its website the American Virtual University explained that the term 'virtual university' is used to describe any organization that provides higher education programs through electronic devices such as the computer. The same website further explained that some of the universities are real institutions, the bricks and mortar type that provide online learning as part of their extended university courses, while others provide on-line courses only.

From the definition and explanation of the concept of the virtual university, this writer finds it reasonable and appropriate to research on the ICT infrastructure supporting this ever growing phenomenon of virtual universities. Researching through literature, this researcher found that, according to Brown et al (2002: 1), 'building an enterprise-scale software system is a complex undertaking because the demands imposed by modern information systems frequently stretch to breaking point in any organisation's ability to design, construct and evolve mission-critical software solutions. As a result, few brand new systems are designed from scratch; rather, software architects' tasks are commonly that of extending the life of an existing solution by describing logic that manipulates an existing repository of data, presenting existing data and transactions through new channels.

This researcher also found that Brown et al (2002) identified specific terms used to define elements within web services; services which are a logical entity, i.e. the contract defined by one or more published interfaces; service providers which are the software entity that implements a service specification, and service requestors (clients) which are the software entity that calls a service provider. Understanding these terms, in this writer's opinion, assists with understanding the ICT architecture supporting virtual universities and leads to service oriented architecture (SOA).

With the SOA architecture Brown et al (2002) explained that there is a service locator which is a specific kind of service provider that acts as a registry and allows for the lookup of service provider interfaces and service locations. There are also service brokers who are in effect service providers that can pass on service requests to one or more additional service providers, (Brown et al 2002).

In addition to the five specific terms used to define elements within web services as identified above, Brown et al (2002) also identified six key characteristics for the effective use of services which in this writer's opinion are important to understand when implementing a virtual university. The six characteristics are coarse-grained, interface-based design, discoverable, single instance, loosely coupled and asynchronous. When explaining the term coarse-grained, Brown et al (2002) wrote that it is the operations on services which are frequently implemented to encompass more functionality and operate on larger data sets, compared with component-interface design where interface-based design would be referring to a design where multiple services can implement a common interface and a service can implement multiple interfaces.

Brown et al (2002) explained that services need to be found at both design time and run-time by both unique identity and interface identity, as well as by service kind. The same authors also explained that each service is single, always running instances that a number of clients communicate with. 'Loosely coupled' refers to services which should be connected to other services and clients using standard, dependency-reducing, decoupled message-based methods such as XML document exchange. The final of the six characteristics is asynchronous and this is where services should be able to use an asynchronous message passing approach.

After identifying the specific terms and characteristics Brown et al (2002) presented four different types of designs, namely: layering application design, component-based design, service-oriented design and caching in service-oriented design. Brown et al (2002) found that object-oriented technology and languages are great ways to implement components but cautioned that one has to understand the trade-offs made through decisions and implementations concerning inheritance versus aggregation for implementing polymorphic behaviour, or redesigning of class libraries.

The findings and comments of Brown et al (2002) in relation to layering, the first design, are consistent with Bass et al (2013: 206) who also explained that 'the software needs to be segmented in such a way that the modules can be developed and evolved separately with little interaction among the parts supporting portability, modifiability and reuse.'

The second design is the component-based design. Brown et al (2002) explained that the key for existing component platforms is the common pattern meaning that for each attribute in the analysis class, two operations have to be provided. It was also made clear that for local components the overhead of a method call is negligible and for remote objects the remote procedure call mechanisms are optimised to minimise overheads.

The service-oriented design is the third design which, as explained by Brown et al (2002), is where for each service there is a single instance that manages a set of resources. Therefore, a service has to be viewed as a manager object that can create and manage instances of type or set of types.

In a magnificent way Brown et al (2002) also mentioned the passing of state from provider to requestor explaining that it implies that rather than a large number of small operations to retrieve the component state, a single large operation is used. The use of a single large operation is ideal for a virtual university considering the possible high traffic and demand of services expected. From the identified literature, this writer therefore concludes that service oriented architecture is the ICT architecture which is ideal for supporting virtual universities.

3. Business to business integration

The interactions among the three parties are shown in the following diagrams. The first represents the virtual university to student's interaction, the second representing the online service to student interaction and the final

demonstrates the service which students need. The diagram below, illustrates the virtual university-students relationship. In this relationship system users of the virtual university log onto the virtual university intranet using their own browser and then are authenticated with the system. From the virtual university home page, logged on virtual university system users are able to access the service website. When there is an authenticated connection, credentials for virtual university system users are communicated following a WS-Federation protocol to any service, which directly authenticates and grants access to its ordering system to the virtual university system users. At this point the web service enabled browser will interact with the web service that the students provide for placing orders. The virtual university's web service retrieves and updates information from the student database, ensuring integrity of the messages exchanged by using WS-Security to sign messages sent by both parties.

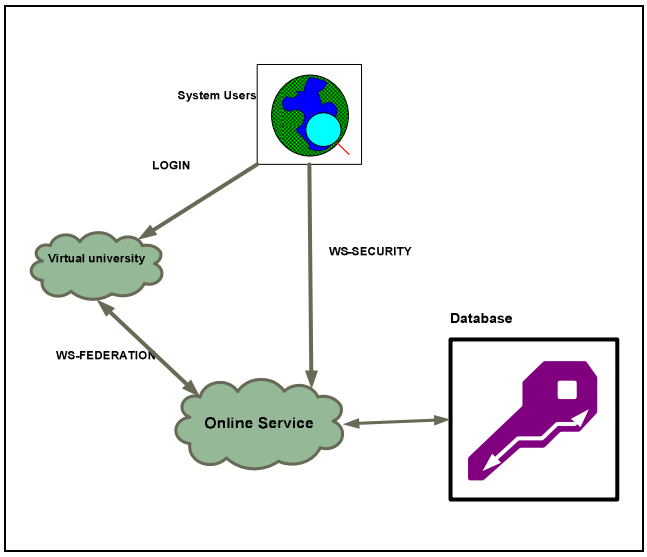

Figure. 2 VU to Online Service Integration

4. Web services architecture

This section describes component technologies that make up the Web services stack and focuses on particular components of the Web services architecture stack, as illustrated in Figure 3.

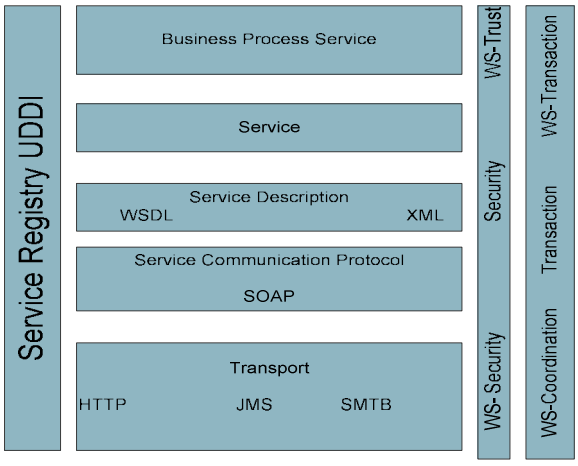

Figure. 3 Components of the Web Services Architecture Stack

4.1 Transport layer

Transport layers are mechanisms used to move service requests from the service consumer to the service provider and service responses from the service provider to the service consumer. This is a use of HTT protocol standards for the transport of service requests and responses. It also uses JMS as Messaging middleware for accessing existing enterprise systems in an asynchronous manner and uses Simple Mail Transfer Protocol (SMTP) to transfer electronic mail reliably and efficiently from people to people.

4.2 Service Communication Protocol layer

Service communication protocol layers describe and define the technologies and standards required to supply a transport mechanism between integrated services (point end point).

4.2.1 SOAP

SOAP is used to exchange data between systems. According to Webber and Parastatidis (2009) the origins of web services focused on the point-to-point integration of applications in a heterogeneous computing environment, employing SOAP and-RPC convention to invoke methods on remote objects in a classic client server pattern. SOAP which provided a set of rules marshalling and unmarshaling of graphs of applications-level objects as well as the familiar envelope structure, which together formed a crude but workable XML-based RPC system . SOA explained by Bih (2004) quoting IBM (2004) is consisting of three participants and three fundamental operations; service provider, service requester and service broker and explained that the 'three SOA participants interact through three basic operations: publish, find, and bind. Service providers publish services to a service broker. Service requesters find required services using a service broker and bind to them. The interactive process among these three agents calls/centres on the service components rather than objects which characterizes object paradigm. SOAP messages supports publish, find and bind operations in the Web Services architecture.

4.3 Service Description Layer

The Service description layer is one of the main benefits of Web Services is to allow for loosely coupled architectures. For example, business context is described using a Universal Description, Discovery and Integration (UDDI) data structure which are a registry that contains relatively lightweight data with the prime purpose of providing network addresses to the resources it describe. (UDDI) service provides methods of querying a web service registry to determine the availability of specific services. In the setting, a requestor queries a registry with a WSDL query, to which the registry responds with the protocol of how the requestor may interact with the requested web services, (Sebesta, 2008). Web service is defined as being network-accessible via SOAP and represented by a service description, the first three layers of this stack are required to provide or use any Web service. The simplest stack would consist of HTTP for the network layer, the SOAP protocol for the XML messaging layer and WSDL for the service description layer.

4.3.1 XML

XML is a simple human-readable representation of data. It used in defining a message in a Web service. It allows for a customized mark-up language with tags defined in a Document Type. Moreover, XML is better way integration of management data from disparate sources therefore the XML has been accepted widely in IT.

4.3.2 WSDL

Web Services Description Language (WSDL); Universal Description and Discovery (UDDI); and SOAP formed the original Web Services specification. WSDL describes Web services starting with the messages that are exchanged between the requester and provider agents. WSDL is an XML-based format published for describing Web services that are implemented by using SOAP. It provides a simple way for service providers to describe the format of requests and response messages for remote method invocations (RMI). The W3C has adopted the Web Services Description Language (WSDL) as a standard for base-level description. WSDL specifies the operational characteristics of a Web service using an XML document.

4.4 Service layer

The service layer represents the implemented software that can be located and invoked based on a published WSDL interface description.

4.4.1 Web Services and J2EE

Web services are intended to provide interoperability between systems, regardless of the architecture or implementation approach of end-point systems. According to Little et al (2004) in J2EE, the standard mechanism for looking up a JMS administered object is via JNDI and to support it, application servers have to allow users to map the client view of JSM into their managed naming environment

4.5 Business Process layer

This layer are using industry standards, Web services can advertise their interfaces and be discovered and invoked upon and communicate with each other to deliver. Which using a consistent modelling approach simplifies communication between all parties involved in the business process and communicate with each other to deliver end-to-end functionality by creating and linking together activities which are supplied via Web services.

4.6 Security Layer

SOAP sends a lot of messages designed to expose the increasing occurrence of breached privacy of data as it moves over the insecure Internet. It is possible to attack in all the traditional ways that network traffic is hijacked, redirected or blocked although SOAP makes sure the interoperability between distributed systems dealing with different security domains remains a critical issue. Therefore from a security perspective, like any other computer system Vusa have four goals: data confidentiality, data integrity, system availability and privacy. According to Tatenbaum (2009), the recommendation of the most appropriate program to be implemented for Vusa is cryptography. Knudsen (1998) agrees that cryptography provides security to a system because it is the science of secret writing. Because Vusa as a system needs assurance that users are who they claim to be, this therefore creates the need for authentication. All this boils down to ensuring that a client computer has to be sure that it is talking to a legitimate server (authentication) and it also wants to be sure that any information it transmits is not subject to eavesdropping (confidentiality). Cryptograph provides stronger methods of authentication by means of digital signatures and certificates. Digital signatures allow Web servers and clients to use advanced cryptographic techniques to handle identification and encryption in a secure manner (Hunter and Crawford, 2001). There are two different authentication methods, namely: http authentication and form-based authentication. For the reasons explained below, Vusa is used to implement form-based authentication. For the sake of being more specific, this section will focus on three aspects of security that are commonly supported by JMS providers and these are authentication, authorisation and secure communications (Monson-Haefel and Chappell, 2001).

4.6.1 Authentication

Monson-Haefel and Chappell (2001: 136) explained that 'authentication verifies the identity of the user to the messaging system; it may also verify the identity of the server to the JMS client.' From the same authors this writer learnt that the most common kind of authentication is a login screen that requires a username and a password. The username and password are supported explicitly in the JMS API when a connection is created, as well as in the JNDI API when an initial context is created (Monson-Haefel and Chappell, 2001).

4.6.2 Authorisation

On the aspect of authorisation or access control, Monson-Haefel and Chappell (2001) explained that is an important step in the security process where intelligent decisions had to be made about what a specific user is allowed to do. Authorisation is important in that it is the process that applies security policies that regulate what a system user can do and cannot do within a specified system.

As for Vusa, because there will be different types of users - students, tutors and administration staff - there is a need to access control. This will be achieved by having different user groups which would be part of the larger group.

4.7 Transaction layer

In order to build reliability into a distributed architecture such as Web services, for maintaining data consistency and integrity, the transaction layer of stack contains the WS-Coordination and WS-Transaction standards.

5. Strength and weaknesses of SOA applications

Having confirmed and agreed that SOA is the ICT architecture which is ideal for supporting virtual universities it is reasonable to research its own strengths and weaknesses. Three researches, Wenzel et al (2009), Wang et al (2011) and Kabbani and Tilley (2011) all concurred that communication within the internet transaction protocol relies on standardised SOAP messages, a property which prepares the WS-BA standard inherently for cross-organizational use as participants in the transactions do not have to physically reside in the same SOA-based system or share anything other than a communication channel. The second strength is in the form of the advantage of the WS-BA transaction model because services can register a participant with the coordinator, then forget about it. The coordinator will call the functions on the participant later when appropriate (Wenzel et al, 2009).

However the major weaknesses according to Kabbani and Tilley (2011) are in SOA security. Kabbani and Tilley explained that information security is usually seen as a combination of three core goals: confidentiality, integrity and availability (CIA) forming the foundation to accountability, authenticity, authorization, non-repudiation and identification. However in the world of SOA, many of the known Web systems' vulnerabilities and attacks are also applicable to SOA, such as buffer overflow, SQL injection and session hijacking. Besides these technical challenges there are also some challenges of virtualising university education.

6. Challenges of virtual universities

In addition to the already mentioned challenges, virtual universities face challenges in areas of effectiveness and inadequately equipped e-earning systems which can result in frustration, confusion and reduced learner interest (Georgieva et al, 2003). The same authors further explained that virtual universities' multimedia-based systems suffer from insufficient learner-content, inter-activity and flexibility because of their passive and unstructured way of presenting instructional content. Under such a system, learners have relatively little control over the knowledge structure and the learning process to meet individual needs. Although the identified pieces of literature in this paper

indicated that there are serious challenges to virtualising university education, a most recent research by Jones (2013) indicated that the positive impact of technology in education; wikis, blogs, social media, mobile learning devices, open source tools and cloud computing are all leading and strongly persuading virtualising education. The same research indicated that communication between lecturers, tutors and students in 'virtual' lectures and tutorials using collaborative platforms such as Googledocs, Facebook and Glass Board enabled the lecturer and tutors to communicate seamlessly with students in 'lectures' and 'tutorials', in groups, sub-groups and individually. Therefore this writer, as a final note, is persuaded to conclude that besides all the challenges, technical and non-technical virtualising university education is the future.

7. Summary and conclusions

The paper established that virtual universities reach out to different people and lowers the operating costs associated with campus infrastructure; SAO is the de-facto architecture supporting virtual universities. After identifying the strengths and weaknesses of SOA and the challenges of virtualizing university education, in addition to the model illustrating the use of SOAP, WSDL, WS-Addressing, WS-Policy, WS-Security, WS-Reliable Messaging and WS-Atomic Transaction were all explored to address a business to business integration scenario that could promote virtualising universities. Although the illustration does not include a critical discussion of what implementation platform or technology any of the parties use it provides an explanation as to how Web services work and provided a clean architecture for building integrated business-to-business applications. The paper concludes that SOA is the ideal architecture to support virtualising university education and concludes that virtualising university education is the future.

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