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Full Length Research Paper

Analysis of enterprise service buses based on information security, interoperability and high-availability using Analytical Hierarchy Process (AHP) method

Zeeshan Siddiqui[1,2], Abdul Hanan Abdullah[1], Muhammad Khurram Khan[3]* and Khaled Alghathbar[3,4]

[1]Faculty of Computer Science and IS, Universiti Teknologi Malaysia (UTM), Skudai Johor, Malaysia.
[2]Department of Software Engineering, College of Computer and Information Sciences, King Saud University, Saudi Arabia.
[3]Center of Excellence in Information Assurance, King Saud University, Saudi Arabia.
[4]Department of Information Systems, College of Computer and Information Sciences, King Saud University, Saudi Arabia.

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This research study stresses upon the comparative analysis between commercial and non-commercial Enterprise Service Buses (ESB) for large-scale organizations. We have used Multi Criteria Decision Analysis (MCDA) method known as Analytical Hierarchy Process (AHP) based on three criteria that is Information Security (IS)**, Interoperability and High Availability (IHA). Many comparative analysis reports and papers are available having proven results of comparing non-commercial ESB(s), however, very few reports were found having performed their analysis on commercial ESB(s). We have performed this analysis on the basis of mathematical and graphical proofs by comparing commercially known ESB that is Oracle ESB with two non-commercial yet very famous ESB(s) that is Mule and Fuse. This research analysis will motivate decision makers to choose the best rated ESB on the basis of our criteria. To achieve our objective, we have presented the problem as hierarchy, established the priorities, criteria, and performed mathematical computing and presented graphs to prove our analysis.**

Key words: Software engineering, service oriented architectures, enterprise service bus, multi criteria decision analysis, analytical hierarchy process, information security.

INTRODUCTION

Interoperability or application integration is the fundamental requirement for organizations and enterprises to exchange information between different systems or dissimilar platforms. The interoperability problems get more crucial when integration is required not only between dispersed applications of one domain but require other platform dependent applications to exchange information. Information is being received at the receiving-end should be the same and accurate as it was sent from the sender. Therefore, information security assurance plays a vital role while integrating or interoperating systems together. During crucial time and operational pressure, the middleware architecture should be highly available and its performance should be the same as it was during normal operations. Without achieving information security, interoperability and high availability, the middleware architecture or framework lacks what it is meant to build for. Taking into consideration the current global situation, the need of a highly interoperable, secure and efficient System of Systems (SoS) is increasing day by day. Therefore, these three factors are the main criteria of our study analysis that is Information Security (IS), Interoperability and High Availability (IHA) Tork (2003), DoDAF (2009) and

*Corresponding author. E-mail: mkhurram@ksu.edu.sa.

Alghamdi and Siddiqui (2010).

These days, Enterprise Service Buses (ESB), are widely used as middleware solutions to provide high end integration between different systems. In this research we have analyzed and compared three ESB(s) that is one commercial and very well known ESB Oracle ESB (OSB) and two open source ESB(s) Mule ESB and Fuse ESB. This research is to motivate the decision makers to adopt the best suited ESB for their middleware architecture on the basis of our criteria. Our analysis is on the basis of their features and market survey (David, 2004; Demed and Berry, 2007; Dossot. et al., 2010; Progress, 2009; Alghamdi, 2009; Demed and Dave, 2004).

METHODOLOGY

Multi Criteria Decision Analysis (MCDA) or often called Multi Criteria Decision Making (MCDM*)* (Linkov et al., 2004) is a technique that contains regulated set of methods that helps decision makers to decide or to make critical decision on the basis of several criteria orbiting that decision. The MCDA methods are very well suited when verdict makers have to take decision on numerous and disagreeing evaluations.

The method which we use in our rest of the discussion is Analytical Hierarchy Process (AHP). AHP is the most recommended and most suited method that was developed in 1980 by Saaty. The Saaty's (1980) study that was used is being implemented in many multinational large scale government and private organizations (Berritella et al., 2007; McCaffery, 2005; Robert, 2006; Stein et al., 2007; Ken et al., 2006; Grandzol, 2005; Alghamdi, 2009; Lori, 2006; Tobias et al., 2009). The AHP methodology starts with the goal which comes at the top of the hierarchy and that hierarchy further categorized in criteria, sub-criteria and alternatives. These entities are called parent and child nodes, group of related child nodes will form assessment groups. The parents of an option from different assessment groups are called its covering criteria. The AHP process which we have used in this analysis is known as Pair-wise comparison (Saaty, 2000, 2009; Alghamdi, 2007; Forman et al., 2001; Saaty et al., 1992).

The pairwise comparison process

This process can easily be understood by an example: Suppose that we have two cars; Car A and Car B. If one has to choose the best car between A and B. Then the option in this situation is how many criteria to select and which one is more important? Let's consider two criteria that is cost and safety, safety is more valuable as compare to cost, but if the budget is less, then you would not be able to buy the car. The pair-wise comparison gives you a much enhanced and affordable decision that is acceptable and un-contradictory at the same time. There are four steps of hierarchy (Saaty, 1980, 2000, 2009) illustrated in Figure 1, to be observed during the pair-wise comparison process, the hierarchy steps are given thus.

In this study our *goal* is 'analysis of ESB(s) using AHP', our 'alternatives' are 'Oracle, Mule and Fuse ESB(s)', 'criteria(s)' are 'IS, IHA'. In our AHP pair-wise comparison we have made three pairs that is firstly, we have compared Mule ESB with Oracle OSB, secondly, we did the comparison between Mule ESB and Fuse ESB and our third comparison was between Oracle OSB and Fuse ESB.

We have assigned priorities based on Saaty's scale (Saaty, 2000) and Saaty et al. (1992) of relative importance having different intensity rates that is odd number (1, 3, 5, 7, and 9) and different

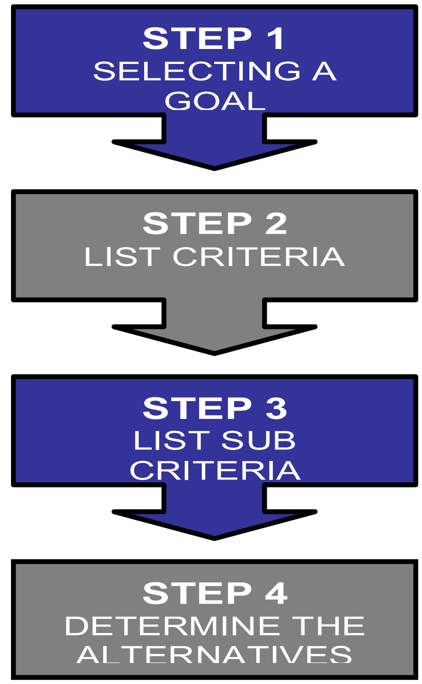

Figure 1. Analytical hierarchy process steps.

decisive factors. Intensities or factors of even numbers that is 2, 4, 6, 8 can also be used to state halfway values. Intensities 1.1, 1.2 and 1.3 etc can be used for elements that are very close in importance. In our pair-wise analysis and computing steps we will build hierarchy, assign priorities and scales, calculate weight, list comparison methodology, perform mathematical computation and finally compute the priority vector, this all have been discussed.

RELATED STUDY

The related study of AHP in particular is unfathomable as it roots from 1970's. Below are some of the researches among many in which AHP is used as a major decision support method and tool in different organizations also we will outline few analysis reports in which comparative analysis is performed on different ESB(s). Berritella et al. (2007) implemented AHP method to decide the best way to reduce the global climate change. Software systems quality have been quantified by Microsoft Corporation by using AHP method (McCaffery, 2005).

Robert applied Vollmer and Gilpin's assessment criteria on two open source ESB(s) that is Apache Server Mix and Mule Source Mule. A wide range of criteria was covered including offerings, strategy, pressure and integration. He rated Mule ESB best among all of them. Other ESB(s) that he included are: BEA system Aqualogic Service Bus, IBM WebSphere, Enterprise Service Bus and Apache Service Mix (Robert, 2006).

Another comparison of both the two listed above that is Apache Service Mix and Mule ESB and two commercial ESB(s) that is IBM WebSphere ESB and BA system Aqualogic Service Bus is done by Stein et al. (2007) on performance and high availability. Open ESB(s) were rated on top of the commercial ESB in his analysis.

A very informative evaluation was done by Vollmer and Giplin, they appraised eight commercial ESB(s) on hundred criteria which were further divided into three groups that is market pressure, current offerings and strategy. They marked cape clear on top of every one (Ken et al., 2006).

Grandzol, compared and presented much more improved method for faculty selection which is currently being implemented in Higher Education at University of Bloomsburg Pennsylvania (Grandzol, 2005). Alghamdi (2009), used AHP to assess the best suited architecture framework for C4I system.

Integration, price and features were observed and evaluated by Vitties (2006) on commercial ESB(s). He pulled BEA Aqualogic on top level and Oracle ESB (OSB) on second position. His information was based on the survey done from customers and was based on previous studies (Lori, 2006).

Tobias et al. (2009) compared free and open source ESB(s) that is Fuse ESB, Mule ESB and Open ESB. He placed Fuse on top. This study discovered the need to identify significant information resources and expose them through loosely coupled, reusable, and compassable services for successful composition into workflows.

ESB(S) overview and product wise comparison

We will compare the product outline of three ESB(s) on the basis of information security, interoperability and high availability.

Oracle ESB (OSB)

Oracle, a market colossal, very matured do-it-all vendor. Oracle is a promising vendor from more then three decades providing working prototype for a relational database. Today Oracle is the bullion standard for database technology and applications in enterprises right the way through the globe. Oracle was the foremost organization that provided its business applications through internet. Oracle has a huge product line from A to Z. That covers almost every aspect of database technology, business applications, development of applications and decision support tools. Oracle is offering its market leading product named as OSB. The most recent version launched is Oracle Service Oriented Architecture (SOA) suite 10.1.3. Oracle ESB is a part of Oracle SOA suite (Ken et al., 2006).

Oracle ESB is built on the standard of Business Integration, focuses on: Business Process Management (BPEL), ESB, Enterprise Messaging Service (EMS), Oracle Data Hub (ODH), RFID and Sensors (SES), Partner Integration (B2B), Enterprise Connectivity (Adapters), Business Activity Monitoring (BAM) and SOA. [Oracle, http://www.oracle.com/identity (2004)].

Oracle ESB is a part of the oracle fusion middleware family. This family featured oracle application server 11 g, data hubs, oracle collaboration suite and Oracle SOA ENTERPRISE architecture suite. The security product that deals with this family is Oracle Identity Management. This product covers every aspect of identity management such as; web access, identity administration, user provisioning, federation of identities and web services integration across desperate operating systems, directories, application servers and applications, for more information Oracle, http://www.oracle.com/identity (2004). Oracle has a massive number of partner lists, the count is 6932 partners world wide covering 21 industrial sectors that no-one is covering till date Oracle, http://www.oracle.com/identity (2004).

Mule ESB

Mulesource known as Mulesoft these days, is by far the most widely used open source ESB with over 1.5 million downloads and 2500 production deployments. Founded in 2006 and backed offices worldwide, in September 2009 Mulesource changes its name to Mulesoft. The main role of Mulesoft orbits around open source SOA architecture infrastructure software. There are several products: Tcat Server, Mule ESB, Mule Data Integrator, Mule MQ and Cloudcat (Dossot et al., 2010; Tobias et al., 2009).

Mule ESB provides a very solid engine for mediation, routing, and lightweight orchestration. Mule ESB has two versions; Mule ESB community and Mule ESB enterprise. The Mule ESB enterprise is only available for subscribers.

Many security bugs have been reported to Mule at the end of September 2009 related to their WSS4J validation. Major limitation of the Mule ESB is that the architects and developers should work directly with XML files to define the flow of activities. Mule ESB runtime and architecture notch-ups imitates its immaturity. Breadth of offerings is not present which we can observe in many other mature ESB(s). The “PAID” option for most required and valuable offerings dissolves the idea of a complete open source ESB, especially the paid technical support (Tobias et al., 2009).

Recently Mule ESB has launched Mule IDE 2.0. Mulesoft has covered five industrial areas, the list includes: System integration partners, service provider partners, independent software vendors, value added reseller and OEM partners (Tobias et al., 2009).

Fuse ESB

Fuse ESB is a fuse open source community (Progress, 2009; Joseph et al., 1981) a part of Progress Software Corporation [Progress History, http://web.progress.com/en, (1981)]. Progress Software roots back to 1981 focuses on application development and deployment software. In fiscal year 2008, Progress Software acquired Mindreef Inc. which had developed and marketed the award wining Mindreef SOAP scope products, which enables business analyst, system architects, application developers, testers, operations and support staff to build, deploy and maintain better software at each phase of an SOA. [Progress History, http://web.progress.com/en, (1981)]. Fuse open source community has a range of product list includes: FUSE ESB 3 and 4 based on Appache ServiceMix 3 and 4 respectively, FUSE message broker, FUSE service framework, FUSE mediation router, FUSE integration designer and FUSE HQ.

ESB tabular product comparison

We compare the complete product outline of all the three ESB(s) which we are discussing from the beginning. We present our comparison in the tabular format in Table 1 to give a systematic view point for detail analysis.

AHP pairwise computation and resultant/eigen vector

We have performed the steps discussed in pairwise computation and resultant. The following Figure 2 demonstrates our hierarchy according to the explanation of Figure 1. In Figure 2, ‘IS’ stands for IS, ‘Ib’ standards for Interoperability and ‘HA’ stands for high-availability. We have compared the ESB(s) based on Saaty’s (Saaty, 2000; Saaty et al., 1992) scale having intensities as defined in Table 2.

On the basis of the detail literature review and product comparison, we assign the weight based on Saaty’s scale (Saaty, 2000) and Saaty et al. (1992) by comparing different ESB(s) together, as illustrated in Figures 3 to 5. In Figure 3 we have assigned ‘3’ that is ‘considerably in favor’ to Oracle when comparing it with Mule because of its state of the art product line covering all aspects of IS, Interoperability and High Availability. In Figure 4 we have assigned ‘5’ that is ‘strongly in favor’ to Mule when comparing it with Fuse. In Figure 5 we have assigned ‘7’ that is. ‘very strongly in favor’ to Oracle when comparing it with Fuse.

Table 1. ESB(S) product line tabular comparison with respect to information security, interoperability and high-availability.

ESB(s)	ESB(s) products with respect to IS, Ib and HA criteria
ORACLE	**Information security products (IS)**
	Identity Management Suite, Access Management Suite, Adaptive Access Manager, Directory Service Plus, Enterprise Single Sign-on, Entitlement Server, Identity Analytics, Identity Federation, Information Rights Management Suite, Role Management Suite, Web Service Suite, Data Transformation Security, Secured Pervasive Enterprise System Connectivity, Content Routing Suite, Access Control, Data Privacy and Compliance Suite, Common Security framework for Middleware security, Open Standards change protection, Open Standards supports: WSDL, SOAP, HTTP(s), Reliable SOAP, WSIF, WS-*, JMS, XSLT, BPEL, JCA, XPATH, X-Query, UDDI, JNDI, J2EE, JDBC, SMTP, FTP
	Interoperability products: (Ib)
	Eclipse based integration development Suite, Browser based tool set for users creating composite applications through process orchestration, Design time tight Integration, Full SOA life cycle management, OSB (Oracle Service Bus) runtime support, Runtime Process Management, Runtime protocols, connectivity options, mediation capability, security and service management.
	High availability products: (HA)
	SOA Suite High Availability, BPEL Process Manager High Availability, OSB High Availability Implementation, WSM configuration in a clustered envoi, ONS topology, Synchronous and Asynchronous node Connectivity, Load Balancer, Multiple Domain Clustering, Dehydration Store Database, Automatic Node Propagation Change Configure
MULE	**Information security products: (IS)**
	Access Management Context using CXF, Access Management Context using WS Security, Secure Web Service using WSS4J connectors, Signature Validation, Audit Trial Log (Failure, Success and Certification Inf), Access to Source Code, Community Extensions, Online Community Forum
	Interoperability products: (Ib)
	Console Management, High Availability and Failover capability, SEDA service event queues, In-memory message queues, High Availability for (HTTP, JMS, Web Sphere, MQ, JDBC, File, FTP, Clustered)
	High availability products: (HA)
	Integrated Service Registry, Retry Policy, Multi resource Transactions, Web Sphere MQ Connector, JDBC Connector, Enterprise SLA's
FUSE	**Information security products: (IS)**
	Secure HTTP compatible bindings, Certificates Management, Https Cipher Suite (SSL V2. V3 / TSL / JCE / JSSE), WS Policy Framework, Message Protection, Authentication System, Lightweight Integration, JBI Support, OSGI Support, Spring Container, Standards based Design (JMS, JCA, JMX support)
	Interoperability products: (Ib)
	Active and standby High availability in service Mix, clustering in service mix, separate Hosts, distributed message routing.
	High availability products: (HA)
	Dynamic deployment, Faster development, Standard message interface, Straightforward integration

Comparison matrix

We have formed 3 × 3 matrix on the basis of comparisons from Figures 3 to 5. The diagonal value of a matrix is always 1, therefore, if the judgment value in the comparison is on the right side then we will put the actual value and if it's on the left side then

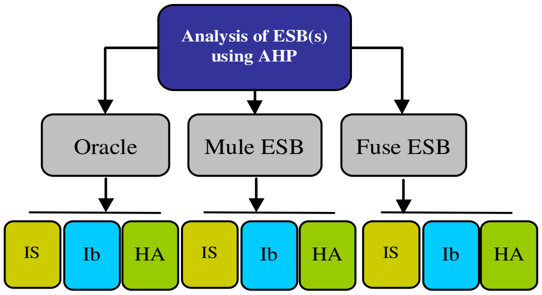

Figure 2. AHP hierarchy.

Table 2. Intensity levels and definitions.

Intensities	Definition
1	Identical
3	Considerably in favor
5	Strongly in support
7	Very strongly in favor
9	Acute favor

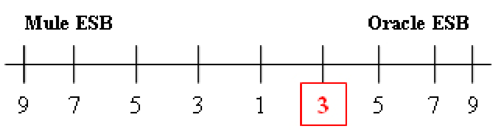

Figure 3. Comparison between mule and oracle ESB(s).

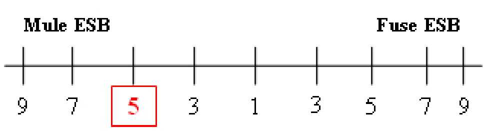

Figure 4. Comparison between mule and fuse ESB(s).

we will use its reciprocal value as stated in Equation (1):

$$\begin{bmatrix} 1 & 1/3 & 5 \\ & 1 & 7 \\ & & 1 \end{bmatrix} \begin{matrix} \text{Mule} \\ \text{Oracle} \\ \text{Fuse} \end{matrix} \quad (1)$$

To fill the lower curl of the matrix, we use the reciprocal value of the upper diagonal. Therefore, if *"aij"* is the element of the row *"i"* and column *"j"* of the matrix then the lower diagonal is filled using the below formula:

$$aij \equiv 1/aij$$

Figure 5. Comparison b/w oracle and fuse ESB(s).

The complete comparison matrix based on the above statements is in Equation (2) below:

$$\begin{bmatrix} 1 & 1/3 & 5 \\ 3 & 1 & 7 \\ 1/5 & 1/7 & 1 \end{bmatrix} \begin{matrix} \text{Mule} \\ \text{Oracle} \\ \text{Fuse} \end{matrix} \quad (2)$$

Notice that all the elements in the comparison matrix are positive that is aij > 0.

Computing priority vector

As calculated in above, we have now a "3 X 3" comparison matrix. In further calculations, we have computed priority vector which is basically the "Eigenvector". We suppose that "X" is equal to our comparison matrix in Equation (3).

$$X = \begin{bmatrix} 1 & 1/3 & 5 \\ 3 & 1 & 7 \\ 1/5 & 1/7 & 1 \end{bmatrix} \quad (3)$$

Now we have summed up each column of our reciprocal matrix vertically using LCM method [Math History (2008)], thus we get the following matrix in Equation (4):

$$X = \begin{bmatrix} 1 & 1/3 & 5 \\ 3 & 1 & 7 \\ 1/5 & 1/7 & 1 \end{bmatrix} \quad (4)$$

$$\sum = [21/5 \quad 31/21 \quad 13]$$

We have divided each element of the matrix with the sum of its corresponding column, for example, in the first column we have divided '1' by the sum of its column '21/5' therefore the result is '5/21'. After the division we have normalized relative weight. The sum of each column is '1' using the LCM method. As illustrated in Equation (5) below:

$$X \equiv \begin{bmatrix} 5/21 & 7/31 & 5/13 \\ 15/21 & 21/31 & 7/13 \\ 1/21 & 3/31 & 1/13 \end{bmatrix} \quad (5)$$

$$\sum = [1 \quad 1 \quad 1]$$

We have achieved our normalized principle Eigenvector by averaging that is sum of values / number of values across the rows in Equation (6):

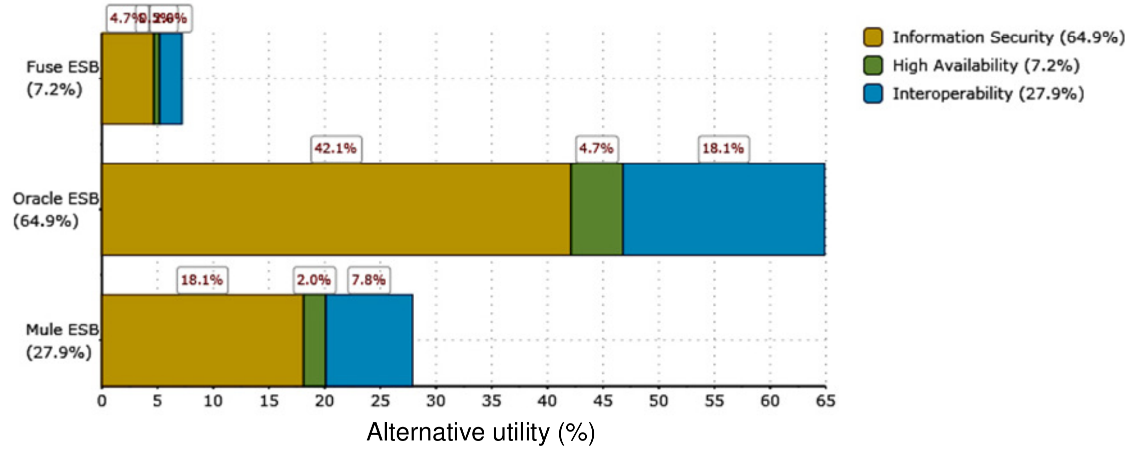

Figure 6. Alternative ranking utility test result.

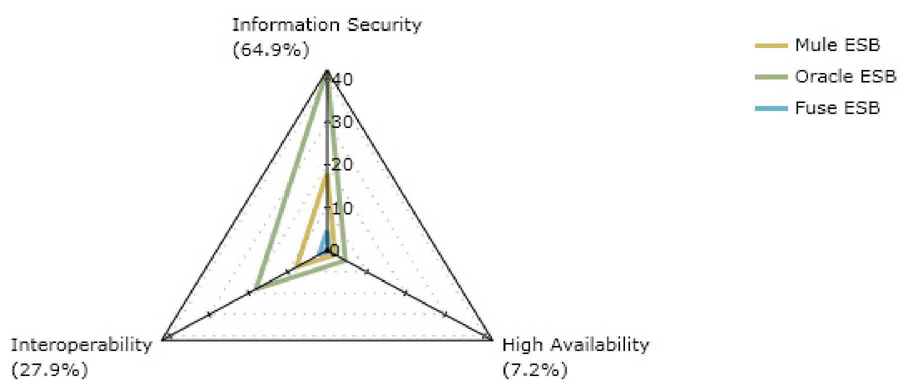

Figure 7. Alternative comparison test result.

$$\equiv 1/3\begin{bmatrix} 5/21+ & 7/31+ & 5/13 \\ 15/21+ & 21/31+ & 7/13 \\ 1/21+ & 3/31+ & 1/13 \end{bmatrix} \quad (6)$$

After summing up the rows, we have Equation (7):

$$\equiv 1/3\begin{bmatrix} 0.8484 \\ 1.93 \\ 0.2212 \end{bmatrix} \; OR \equiv \begin{bmatrix} 0.8484/3 \\ 1.93/3 \\ 0.2212/3 \end{bmatrix} \quad (7)$$

Below is our resultant Eigenvector which is equal to '1' in Equation (8):

$$\begin{bmatrix} 0.2828 \\ 0.6434 \\ 0.0738 \end{bmatrix} \equiv 1 \begin{matrix} \text{Mule} \\ \text{Oracle} \\ \text{Fuse} \end{matrix} \quad (8)$$

RESULTS AND DISCUSSION

The resultant of priority or eigenvector should always be '1'; therefore, Equation (8) shows the relative weight among different ESB(s). Mule ESB is 0.2828 or 28.28%, Oracle ESB is 0.6434 or 64.34% and Fuse ESB is 0.0738 or 7.38%. Therefore, Oracle ESB is more preferable followed by Mule ESB and Fuse ESB. Although, we can calculate the ratio scale from the relative weights that is, we can state that Oracle ESB is 2.27(=64.34/28.28) times more preferable than Mule ESB and 8.72 (=64.34/7.38) times more preferable than Fuse ESB. If we add the percentages that is 64.34 + 28.28 + 7.38% than the sum is 100%.

Proof test using existing AHP utility

There are many softwares built using different MCDM techniques and methods to solve critical decision making issues. Many of that software are freeware and share-

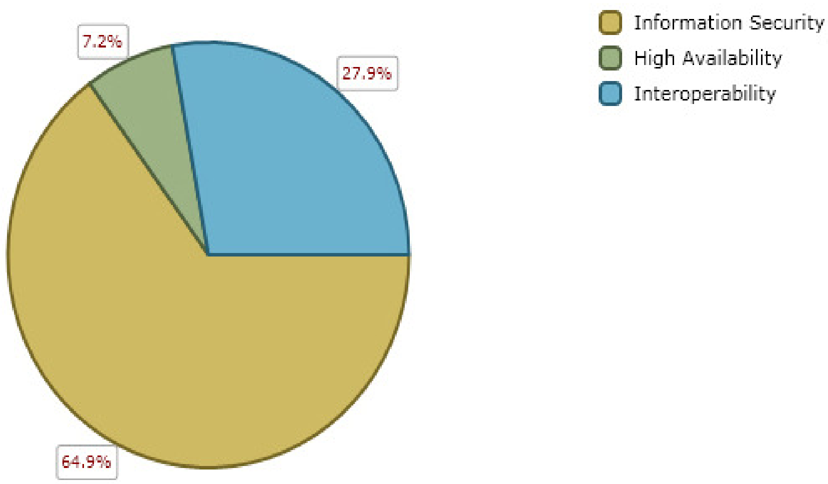

Figure 8. Pie-chart showing sub-criteria weight.

ware, for example, MakeitRational, MACBETH, 1000Minds, Athena, Decisionarium and many more (Alghamdi and Siddiqui, 2010). We have performed three tests; Alternative Ranking Test, Alternative Comparison Test and Sub-criteria Weight Test by using 'MakeitRational' to proof our results above. 'MakeitRational' application is AHP decision application build on AHP standards by BS consulting Dawid Opydo. This project is co-funded by European Union. Graphs and charts presented using MakeitRational from Figures 6 to 8 will be discussed.

Alternative ranking test discussion

In Figure 7, successful pair-wise comparison analysis performed using 'MakeitRational' AHP decision software explains that the criteria weight-age of Fuse ESB by comparing it with Oracle ESB and Mule ESB with respect to "IS" is 4.7%. criteria "HA" weight-age is 0.7% and criteria "Interoperability" is 2.3%. By comparing Oracle ESB with Fuse ESB and Mule ESB, weight-age is 42.1% of "IS" criteria, 4.7% with respect to "HA" and 18.1% for "Interoperability".

The comparison of Mule ESB with the other two ESB(s) proves that the weight-age is 18.1% for "IS", 2.0% for "HA" and 7.8% for "Interoperability". Therefore, Oracle ESB is comparatively highly ranked in our alternative ranking test.

Alternative comparison test discussion

The same has been observed in the alternative comparison in Figure 8. The alternative comparison percentage in tri-chart is 64.9% for "IS", 27.9% for "Interoperability" and 7.2% for "HA" with respect to Oracle ESB. Oracle ESB is also highly ranked as compared to other ESB(s).

Sub-criteria weight test discussion

The weight-age of the sub criteria in Figure 8 shows that "IS" is 64.9%, 27.9% is for "Interoperability" and 7.2% "HA". This also proofs that the information security assurance is the main achievement in any middleware architecture. By adding the percentages that is 64.9 + 27.9 + 7.2%, the result is 100%. Therefore, this has confirmed our mathematical calculations. It clearly demonstrates the equivalence of our test result percentage using MakeitRational AHP software with eigenvector percentage derived from our computations.

CONCLUSION AND FUTURE WORK

The priority vector shows the relative weight among different ESB(s) in which, Mule ESB is 0.2828 or 28.28%, Oracle ESB is 0.6434 or 64.34% and Fuse ESB is 0.0738 or 7.38%. Therefore, Oracle ESB is more preferable followed by Mule ESB and Fuse ESB. After all these observations, we came to the conclusion that Oracle ™ ESB supports critical data integration, information security assurance and high availability in pressure intervals. Therefore, whether organizations involve in-house system integration or integration of resources between different organizations on different platform, Oracle ESB is the best choice to adopt, implement and relay-on to achieve high interoperability, information security assurance and high availability.

We are planning to extend this study with respect to analysis and decision making by performing consistency calculations and sensitivity analysis in our further studies.

In order to achieve more stronger and more absolute analysis to help the decision makers to choose the best suited middleware architecture for their critical business architecture.

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