

Toward a Comprehensive Framework for Evaluating the Core Integration Features of Enterprise Integration Middleware Technologies

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Abstract: To achieve greater automation of their business processes, organizations face the challenge of integrating disparate systems. In attempting to overcome this problem, organizations are turning to different kinds of enterprise integration. Implementing enterprise integration is a complex task involving both technological and business challenges and requires appropriate middleware technologies. Different enterprise integration solutions provide various functions and features which lead to the complexity of their evaluation process. To overcome this complexity, appropriate tools for evaluating the core integration features of enterprise integration solutions is required. This paper proposes a new comprehensive framework for evaluating the core integration features of both intra-enterprise and inter-enterprise Integration's enabling technologies, which simplify the process of evaluating the requirements met by enterprise integration middleware technologies.

The proposed framework for evaluating the core integration features of enterprise integration middleware technologies was enhanced using the structural and conceptual aspects of previous frameworks. It offers a new schema for which various enterprise integration middleware technologies are categorized in different classifications and are evaluated based on their supporting level for the core integration features' criteria. These criteria include the functional and supporting features. The proposed framework, which is a revised version of our previous framework in this area, has developed the scope, structure and content of the mentioned framework.

Key words: Enterprise Integration; Evaluation Framework; Integration Features; Middleware Technologies; Functionality; Information System

1. Introduction

"Application Integration can be defined as an activity that integrates and harmonizes an enterprise's isolated business applications, processes and functions in order to provide common, sharable business applications, functions and services within the enterprise. There are many obvious advantages with application integration. First, it offers more functions and better services than the individual systems. Second, it can reduce data redundancy and function overlapping, hence ensuring a greater degree of data integrity and consistency" (Themistocleous and Irani, 2001).

Although this definition presents a relatively comprehensive view over the area, still limiting enterprise integration to internal functionalities inside an enterprise. Mosawi et al. (2006) have proposed two types of enterprise integration include inter-application integration and intra-application integration.

Intra-application integration [which other references call it intra-enterprise application integration] seeks to incorporate enterprise applications and exchange information at enterprise level. It requires that enterprise systems leverage and integrate into the new business systems. Inter-application integration [which other references call it inter-enterprise application integration] allows enterprise to integrate its business process with its business partner's process, to improve business efficiency.

"Excess of coupling in enterprise integration may result in complexity between applications. For example, one-to-one communications between many applications in an integration solution results in communication bottlenecks. Additionally, changing an application may require changes in the other applications. Therefore, coupling may result in cost increasing. Nowadays, other integration solutions (such as enterprise application integration packages and virtual database) have appeared which make the management of integration easier and more scalable. Intrinsically, every application integration

initiative requires financial investment by an organization" (AUTHORⁱ). Therefore, the evaluation of technologies involved in an enterprise integration project may greatly reduce the cost/benefit risk.

Furthermore, the wide variety of enterprise integration middleware technologies and their associated features, make the evaluation and selection of these technologies too complex. To overcome this complexity, appropriate tools should be used for evaluating the core features of enterprise integration middleware technologies. This paper focuses on offering a new framework for evaluating the core integration features of both intra-enterprise and inter-enterprise integration technologies and answers the following questions:

- What kinds of intra-enterprise and inter-enterprise integration technologies are available in today's IT market?
- What kinds of functional and supporting integration features are provided by intra-enterprise and inter-enterprise integration technologies?

To answer the above questions, we begin our research by the research method section. Then, we have a review on the research process which includes the structure of proposed framework and the research scope, the proposed list of integration technologies and their associated classifications, the proposed list of core integration features, the proposed evaluation framework, and the verification phase. In the next section, we introduce a multi-step process to leverage the proposed framework by experts. After that, we compare the proposed framework with the previous evaluation frameworks and explain our innovations, and finally, we finish the paper with the research conclusions.

2. Research Method

The research method of this paper is based on the objective data gathering and analysis. Objectively, this research may be applicable because its objective is simplifying the integration problem in information system area. The data gathering of this research is based on the literature reviews on enterprise integration's enabling technologies and their integration features as well as evaluation frameworks. Furthermore, the analysis method of this research is qualitative, however to proof our proposed framework, we used an interview with information systems experts as well as running a semi-structured questionnaire with integration experts.

3. Research Process

As shown in Fig. 1, the first step of this research is to propose a new comprehensive structure for evaluating the core integration features of enterprise integration middleware technologies based on our previous framework in this area (Moradi, Bahreininejad, 2010). The proposed structure includes various enterprise integration middleware technologies classified in different classifications and evaluated based on their supporting level for the core integration features' criteria. Based on such structure, the next sections focus on discovering the proposed list of enterprise integration middleware technologies and their associated classifications as well as recommending the proposed list of core integration features.

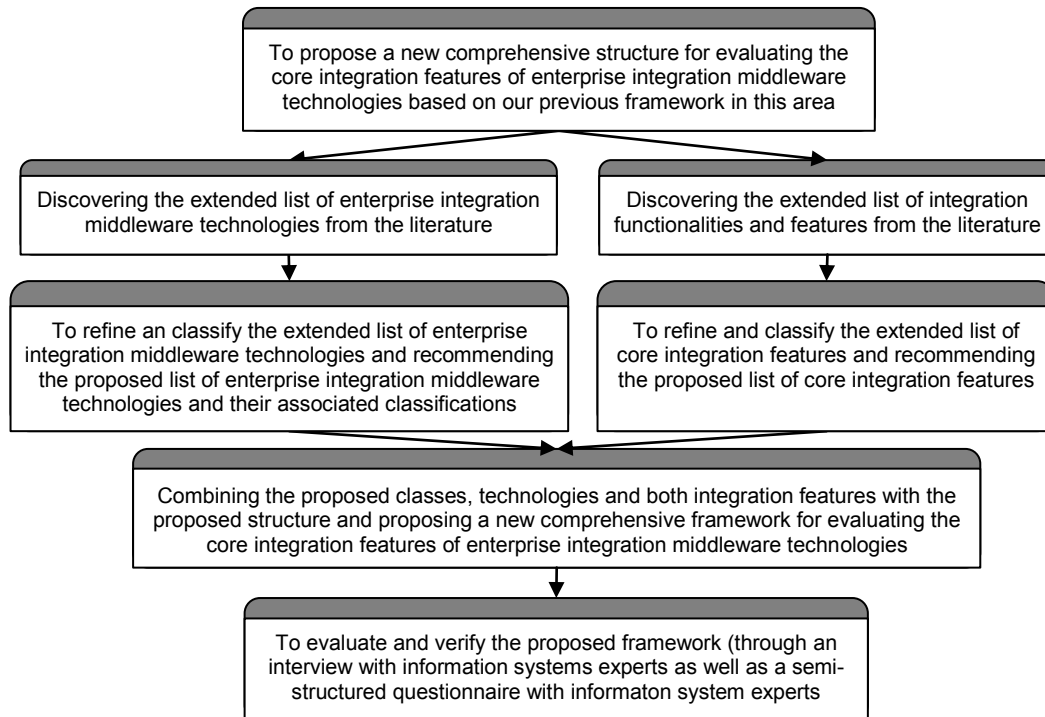


Fig. 1: The major steps of the research process

To discover the mentioned items, we extracted an extended list of integration technologies from literature, and then with the refinement and classification of this list, we identified the proposed list of enterprise integration middleware technologies and their associated classification. In the next step, the extended list of integration functionalities and features was identified. After the refinement, classification and extension of this list, we proposed a new list of core integration features. Then, by the combination of the proposed classes, technologies and core integration features with the proposed structure, a new comprehensive framework for evaluating the core integration features of enterprise integration middleware technologies was proposed. Finally, we evaluated and verified proposed framework through an interview with information systems experts as well as a semi-structured questionnaire with integration experts.

As described above, the research process of this paper includes the following steps dealing with:

- The structure of proposed framework
- The proposed list of enterprise integration middleware technologies and their associated classification
- The proposed list of core integration features
- The proposed evaluation framework
- Evaluation and verification phase

3.1 The structure of proposed framework

The variations in enterprise integration enablers and their features lead to the complexity of selecting the integration technologies. To resolve this complexity, numerous frameworks have been developed (Themistocleous et al., 2004; Themistocleous and Irani, 2002; Brodie, 2006; Puschmann and Alt, 2004; Moradi, Bahreininejad, 2010).

In our previous research in this area (Moradi, Bahreininejad, 2010), we conducted a survey on such frameworks and Themistocleous et al., 2004 and Forrester (Brodie, 2006) frameworks had been chosen. In the mentioned research, we accepted the overall structure of Forrester framework; however, we extended the content and structure of Forrester framework by using the framework proposed by Themistocleous et al., (2004), as well as wide reviewing of EAI¹ literature. Consequently, we proposed a new framework which various intra-enterprise application integration technologies are

¹ Enterprise Application Integration

categorized in different classes, and were evaluated based on their supporting level for functional integration capabilities' criteria (Moradi, Bahreininejad, 2010). The proposed framework had evaluated various application integration technologies based on the following criteria: "messaging, persistence, routing, service-oriented connectivity, information-oriented connectivity, syntactic conversion, semantic transformation, transaction management, business rule management, process management, human workflow management and process monitoring". Furthermore, the evaluated technologies and their associated classification were:

File Transfer Technologies (File Transfer Tools), Elementary Message Oriented Middleware (MOM², Publish/ Subscribe Broker, RPC³, XML⁴), Database Access Technologies (ODBC⁵, JDBC⁶), Application Access Technologies (Application Adapter, Screen Scraper, API⁷), Service-Oriented Technologies (Web Services, ESB⁸), Distributed Object Technologies (CORBA⁹, COM/ DCOM¹⁰, EJB¹¹), Data-Oriented Technologies (Data Replication, ETL¹², Virtual Database), Transaction-Oriented Technologies (TPM¹³, Application Server), Modern Brokers (EAI, BPM¹⁴ Package).

In this paper, we are going to extend the scope of our previous research, so there is a need to propose a new comprehensive framework which cover our extended scope by using an extensive structure and content. In the following paragraphs, we would review the details of our research scope.

As described by Hasselbring (2000), the integration problem can be defined in three levels include the Business level (business to business integration), Application level (application to application integration) and Software Platform level (integration of different software platforms). In this research, we have included three above levels in our research scope, so integration technologies and their associated integration features related to Business level, Application level and Software Platform level have been included in our research scope. Furthermore, both intra-enterprise and inter-enterprise integration technologies and their associated integration features have been included in our research scope.

Also, the supporting features such as security, scalability, development services and etc. which are inevitable software systems' features, have not been excluded from our research scope; however, this framework is not a special one for evaluating the non-functional features of integration solutions.

Furthermore, we just propose a framework to evaluate the technical features of integration tools, and we have not considered the organizational and business aspects of evaluating enterprise integration middleware technologies such as costs, risks, organizational issues, maturity of integration technologies and etc.

Regarding the mentioned research scope, in our proposed structure, various integration technologies have been classified in different classifications, and have been evaluated based on their supporting level for the core integration features. Core integration features' criteria composed of two sections include the functionalities and supporting features' criteria. Just like our previous framework (Moradi, Bahreininejad, 2010) as well as Forrester framework (Brodie, 2006), functionalities is related to the integration functionalities of enterprise integration middleware technologies; however, supporting features is related to the supporting features of integration technologies.

The structure of our new comprehensive framework was shown in Tab.1. Based on this structure, the next sections would focus on discovering the proposed list of enterprise integration middleware technologies and their associated classification as well as recommending the proposed list of core integration features.

² Message Oriented Middleware

³ Remote Procedure Call

⁴ Extensible Markup Language

⁵ Open Database Connectivity

⁶ J2EE Database Connectivity

⁷ Application Programming Interface

⁸ Enterprise Service Bus

⁹ Common Object Request Broker Architecture

¹⁰ Common Object Model/ Distributed Common Object Model

¹¹ Enterprise JavaBeans

¹² Extract, Transform and Load

¹³ Transaction Processing Monitors

¹⁴ Business Process Management

Tab. 1: The structure of the proposed comprehensive framework

		Evaluation Criteria (Core Integration Features)					
		Functionalities			Supporting Features		
		Feature 1	Feature 2	Feature ...	Feature 1	Feature 2	Feature ...
Classification	Integration Technologies						
Class1	Technology 1						
	Technology 2						
	Technology ...						
Class 2	Technology 1						
	Technology 2						
	Technology ...						
Class ...	Technology 1						
	Technology 2						
	Technology ...						

3.2 The proposed list of enterprise integration middleware technologies and their associated classification

In our previous research (Moradi, Bahreininejad, 2010), a list of integration technologies was proposed by extracting the list of integration technologies from application integration literature. In this paper, we adapted this list from Moradi, Bahreininejad (2010) and have developed it by studying the literature of enterprise integration. The results was shown in Tab. 2, although the extended items of this table have been highlighted. Information system experts can use the extended list of enterprise integration middleware technologies to review and better understanding of various enterprise integration middleware technologies.

Tab. 2: The extended list of enterprise integration middleware technologies, extracted from literature (Adapted from Moradi, Bahreininejad (2010) and have been developed in this research)

Technology	Synonyms	Reference
File Transfer Tools		Natis, 2001
Message Oriented Middleware (MOM)	Message Queuing technology	Gulledge, 2006; Natis, 2001; Gold-Bernstein (Evgeniou, 2002); Vandersluis, 2004; Themistocleous et al., 2004 ; Linthicum, 2003; Johnson, 2002; Rizescu, 2006
Publish/Subscribe Broker	Publish/ Subscribe	Gold-Bernstein (Evgeniou, 2002); Natis, 2001; Linthicum, 2003
Remote Procedure Calls (RPC)	Remote Function Call	Gulledge, 2006; Gold-Bernstein (Evgeniou, 2002); Vandersluis, 2004; Themistocleous et al., 2004 ; Linthicum, 2003
Extensible Markup Language (XML)	XML/ XSL	Gulledge, 2006; Themistocleous et al., 2004; Rizescu, 2006
Open Database Connectivity (ODBC)		Themistocleous et al., 2004; Linthicum, 2003
Java Database Connectivity (JDBC)		Themistocleous et al., 2004; Linthicum, 2003
Database Gateway		Natis, 2001; Linthicum, 2003; Johnson, 2002
Application Adapter	Adapter, Connector, Application Wrapper and Gateway	Gulledge, 2006; Natis, 2001; Gold-Bernstein (Evgeniou, 2002); Vandersluis, 2004; Themistocleous et al., 2004 ; Linthicum, 2003; Johnson, 2002
Screen Scrapper	Screen Scrapper Adapter; Legacy screen scraping, Web-based screen scraping	Natis, 2001; Themistocleous et al., 2004; Linthicum, 2003; Johnson, 2002; Rizescu, 2006

Technology	Synonyms	Reference
Application Programming Interface (API)	Application Interface, Component-based Application Interface	Vandersluis, 2004; Mosawi et al., 2006; Themistocleous et al., 2004; Linthicum, 2003; Johnson, 2002; Rizescu, 2006
Web Services		Sapient, 2004; Forrester (Brodie, 2006); Linthicum, 2003; Johnson, 2002
Enterprise Service Bus (ESB)		Tomlinson and Zimmermann, 2005; Forrester (Brodie, 2006)
Common Object Request Broker Architecture (CORBA)		Natis, 2001; Mosawi et al., 2006; Themistocleous et al., 2004; Linthicum, 2003; Johnson, 2002; Rizescu, 2006
Common Object Model/ Distributed Common Object Model (COM/ DCOM)	COM+	Natis, 2001; Mosawi et al., 2006; Themistocleous et al., 2004; Linthicum, 2003; Johnson, 2002; Rizescu, 2006
Enterprise JavaBeans (EJB)		Themistocleous et al., 2004; Johnson, 2002
Data Replication	Database Replication	Gulledge, 2006; Mosawi et al., 2006; Linthicum, 2003; Johnson, 2002
Extract, Transform and Load (ETL)	Data mart and data warehouse technologies, Data Mart and Data Warehouse Loader Technologies	Sapient, 2004; Gold-Bernstein (Evgeniou, 2002); Vandersluis, 2004; Mosawi et al., 2006; Rizescu, 2006; Goldstone T.L, 2011
Virtual Database	Federated Database and Database Federation, Enterprise Information Integration (EII)	Gulledge, 2006; Vandersluis, 2004; Mosawi et al, 2006; Linthicum, 2003; Johnson, 2002; Rizescu, 2006
Transaction Processing Monitors (TPM)		Themistocleous et al., 2004; Linthicum, 2003; Johnson, 2002
Application Server		Gulledge, 2006; Themistocleous et al, 2004; Linthicum, 2003; Johnson, 2002
Enterprise Application Integration (EAI) Broker	Message Broker and Integration Broker	Gulledge, 2006; Johannesson and Perjons, 2001; Sapient, 2004; Tomlinson and Zimmermann, 2005; Natis, 2001; Forrester (Brodie, 2006); Vandersluis, 2004; Themistocleous et al., 2004; Linthicum, 2003; Johnson, 2002; Rizescu, 2006
Business Process Management (BPM) Package	Process Broker	Johannesson and Perjons, 2001; Natis, 2001; Forrester (Brodie, 2006); Mosawi et al., 2006
Electronic Data Interchange (EDI)		Gold-Bernstein (Evgeniou, 2002); Gulledge, 2006
Process or Workflow Modeling, UML		Gold-Bernstein (Evgeniou, 2002)
Supply Chain Integration, On-line Trading Brokers		Gold-Bernstein (Evgeniou, 2002)
BSH		Forrester (Brodie, 2006)
Bridge		Johnson, 2002
P2P		Johannesson and Perjons, 2001; Sapient, 2004
DOT		Vandersluis, 2004
CBD		Tomlinson and Zimmermann, 2005
Transaction Management, Common Application Services, Business Logic, Metadata Management		Gold-Bernstein (Evgeniou, 2002)
Transformation		Vandersluis, 2004

Using information given in Tab. 2, and after refinement and classification of the extracted list of enterprise integration middleware technologies, we could have a new proposed list of enterprise integration middleware technologies and their associated classification.

After refining the extended list of enterprise integration middleware technologies, the shadowed rows of Tab. 2 were eliminated for the following reasons:

- "The P2P¹⁵, DOT¹⁶ and CBD¹⁷ were considered as classes instead of an explicit kind of integration technology. P2P which is a traditional class of integration technologies that includes

¹⁵ Point to Point

¹⁶ Distributed Object Technologies

¹⁷ Component Based Development

RPC and MOM technologies (Linthicum, 2003), were not regarded as an explicit classes in our proposed list. DOT and CBD refer to a similar class of technologies, where we call it "Distributed Object Technologies class" (Moradi, Bahreininejad, 2010).

- "Furthermore, unknown technologies such as BSH and bridge that addressed just by one researcher between twelve researchers" (Moradi, Bahreininejad, 2010), and also in our new comprehensive researches, were not considered as an important technology, were excluded from the proposed list.
- "Finally, transaction management, common application services, business logic, metadata management and transformation which are features of integration technologies, have not considered as an explicit kind of technology, and have excluded from the proposed list of integration technologies" (Moradi, Bahreininejad, 2010); however, we use them to recommend the proposed list of integration functionalities and features in Tab.4.

As suggested by Rizescu, 2006, the main targets of integration in an enterprise are: data, applications and information. Data target could be achieved using a consolidation technology such as ETL tools; however, to realize integration at application level, different kinds of EAI technology could be leveraged, and also to reach integration at information target, data federation using EII technology is the best choice.

Based on the above classification, our suggestion is to add a new class, named Information-oriented technologies to our proposed list of enterprise integration middleware technologies and their associated classification, and insert the Virtual DB or EII technologies into this class. Moreover, regarding this point that file transfer technologies is a kind of consolidation technology, we would insert this kind of integration technology in the class of Data-oriented technologies.

As displayed in Tab. 3, the new proposed list of enterprise integration middleware technologies and their associated classification includes eleven classes of Elementary message oriented middleware (include MOM, Publish/subscribe broker, RPC, and XML), Database access technologies (include ODBC, JDBC, and Database gateway), Application access technologies (include Application adapter, Screen scrapper, and API), Service-oriented technologies (include Web services, and ESB), Distributed object technologies (include CORBA, COM/DCOM, and EJB), Data-oriented technologies (include File transfer tools, Data replication, and ETL tools), Information-oriented Technologies (include Virtual Database, or EII), Transaction-oriented technologies (include TPM, and Application server) and Modern brokers (include EAI broker, and BPM package), Modeler and Simulator Technologies (include Process modeling, and Simulation Tools), and B2B Integration Technologies (include EDI, Supply Chain Integration Tools, and On-line trading brokers). We also have inserted a sample of each technology in Tab 3.

Tab. 3: The proposed list of integration technologies and their associated classification
(Adapted from Moradi, Bahreininejad (2010) and have been developed in this research)

Classification	Integration Technologies	Sample
Elementary Message Oriented Middleware	Message Oriented Middleware (MOM)	<i>MSMQ¹⁸</i>
	Publish/Subscribe Broker	<i>JMS¹⁹</i>
	Remote Procedure Calls (RPC)	<i>DCE²⁰</i>
Database Access Technologies	Extensible Markup Language (XML)	<i>XML Standards</i>
	Open Database Connectivity (ODBC)	<i>ODBC</i>
	Java Database Connectivity (JDBC)	<i>JDBC</i>
Application Access Technologies	Database Gateway	<i>Information Builders' EDA/SQL²¹</i>
	Application Adapter	<i>JCA²²</i>
	Screen Scraper	<i>Ekiwi Screen Scraper Enterprise Edition</i>
Service-Oriented Technologies	Application Programming Interface (API)	<i>SAP's BAPI²³</i>
	Web Services	<i>Web Services Standards</i>
Distributed Object Technologies	Enterprise Service Bus (ESB)	<i>Sonic ESB</i>
	Common Object Request Broker Architecture (CORBA)	<i>CORBA</i>
	Common Object Model/ Distributed Common Object Model (COM/ DCOM)	<i>COM/ DCOM</i>
Data-Oriented Technologies	Enterprise JavaBeans (EJB)	<i>EJB</i>
	File Transfer Tools	<i>FTP²⁴</i>
	Data Replication	<i>Unison (file synchronizer)</i>
Information-Oriented Technologies	Extract, Transform and Load (ETL)	<i>IBM WebSphere DataStage Product Family</i>
	Virtual Database or Enterprise Information Integration (EII)	<i>CONNX Solutions</i>
Transaction-Oriented Technologies	Transaction Processing Monitors (TPM)	<i>Tuxedo Transaction Monitor</i>
	Application Server	<i>WebLogic Application Server</i>
Modern Brokers	Enterprise Application Integration (EAI) Broker	<i>WebMethods Products</i>
	Business Process Management (BPM) Package	<i>Filenet BPMS²⁵</i>
Modeler and Simulator Technologies	Process Modeling and Simulation Tools	<i>BIZAGI Process Modeler</i>
B2B Integration Technologies	Electronic Data Interchange (EDI)	<i>EDI-INT AS2</i>
	Supply Chain Integration Tools	<i>Syncron's SCM</i>
	On-line Trading Brokers	<i>Covisint.com</i>

¹⁸ Microsoft Message Queue
¹⁹ Java Message Service
²⁰ Distributed Computing Environment
²¹ Enterprise Data Access/ Structured Query Language
²² J2EE Connector Architecture
²³ Business API
²⁴ File Transfer Protocol
²⁵ Business Process Management system

As displayed in Tab. 3, we have extended our previous list of enterprise integration middleware technologies and their associated classification (which presented in Moradi, Bahreininejad (2010) research) by regarding four brand new classes and four new technologies include Process Modeling and Simulation Tools (Modeler and Simulator Technologies) and B2B integration technologies (EDI, Supply Chain Integration Tools and On-line Trading Brokers), and Information-oriented technologies (Virtual Database or EII) along with removing the File transfer technologies class and merging its content with the Data-oriented technologies class (File transfer technologies, Data replication and ETL). Remember, the extended items of this table have been highlighted.

3.3 The proposed list of core integration features

By studying the architecture of enterprise integration solutions and reviewing the core features of enterprise integration middleware technologies, the list of integration functionalities and features was extracted from enterprise integration literature and was shown in Tab. 4. This table adapted from Moradi, Bahreininejad (2010) and have been seriously developed in this research. The extended items of this table have been highlighted in Tab.4. This list is a good review of various integration functionalities and features, their synonyms, and the different researchers cited them, and may be used by IT experts to have a review on various kinds of integration functionalities and features.

Tab. 4: The extended list of integration functionalities and features, extracted from literature (Adapted from Moradi, Bahreininejad (2010) and have been developed in this research)

Integration Functionalities and Features	Synonyms	Researchers
Messaging service	Messaging; transportation; communication Services (data transport); Integration Middleware; heterogeneous messaging infrastructure, message priority; Integration middleware	Forrester (Brodie, 2006); Themistocleous and Irani, 2002; Erasala et al., 2003; Goldstone T.L, 2011; Merkel, 2000
Persistence service	Persistence (logging and message warehousing), Repository management	Linthicum, 2003; Goldstone T.L, 2011
Distribution service	Distribution service; Routing; intelligent routing; distribution service (message routing); information routing (one to one, many to many and many to one, intelligent routing and filters); base connectivity (addressing style (peer-to-peer, publish/subscribe or broadcasting) and communication coupling (synchronous or asynchronous)); Intelligent Content Based Routing, Publish/ subscribe services	Puschmann and Alt, 2004; Forrester (Brodie, 2006); Natis, 2001; Erasala et al, 2003; Linthicum, 2003; Hagen (Strüver, 2002); ; Goldstone T.L, 2011
Connectivity service	Connectivity; communication middleware and adapters; resource interface (adapter); connectivity (support for information-oriented connections, service-oriented connections, coupling , cohesion, transaction oriented connections and abstractions); connectivity; connectivity services (communication, addressing, delivery and security services) and interface services (interface translation and metadata representation services); Resource Adapters, pre-built adaptability for all middlewares, Connectivity; Interface Syntax	Forrester (Brodie, 2006); Natis, 2001; Hagen (Strüver, 2002); Linthicum, 2003; Themistocleous and Irani, 2002; Puschmann and Alt, 2004; Goldstone T.L, 2011; Merkel, 2000
Transformation service	transformation (syntactic conversion, and semantic transformation); data transformation; translation; transformation; transformation (support for differences in application semantics, differences in content and abstract data types); transformation services (identification, validation and synchronization services);, Seamless Data Transformation, adapters from applications semantics, syntax; Application semantics	Natis, 2001; Forrester (Brodie, 2006); Themistocleous and Irani, 2002; Hagen (Strüver, 2002); Erasala et al., 2003; Linthicum, 2003; Puschmann and Alt, 2004; Goldstone T.L, 2011; Merkel, 2000
Transaction management service	Transactionality (short-term transaction, long-term transactions and state management); transformation services (transaction processing services); transformation services (transactional integrity); Process flow control (transactional integrity)	Linthicum, 2003; Puschmann and Alt, 2004; Erasala et al., 2003; Goldstone T.L, 2011

Integration Functionalities and Features	Synonyms	Researchers
Business semantics and metadata	Business Semantics; Metadata (message dictionary); interface services (metadata representation services); adapters from applications metadata	Merkel, 2000; Natis, 2001; Puschmann and Alt, 2004; Goldstone T.L, 2011
Process/workflow/rule management service	Business rules; rules; process management (business rules); , Business Rule Management	Forrester (Brodie, 2006); Hagen (Strüver, 2002); Erasala et al., 2003; Goldstone T.L, 2011
	Process management; Business process management (high-speed composite application); intra-broker process control; process automation; Process management (coordinates and controls the transformational services layer); process awareness (support for process management, sub processes, hierarchy, inheritance, service control and information movement); process management services (transformation coordination services);business process,data flow; business processes	Forrester (Brodie, 2006); Natis, 2001; Hagen (Strüver, 2002); Themistocleous and Irani, 2002; Erasala et al., 2003; Linthicum, 2003; Puschmann and Alt, 2004; Goldstone T.L, 2011; Merkel, 2000
	Human workflow; business process management (long-running work flow); inter-application process control (workflow); workflow management	Forrester (Brodie, 2006); Natis, 2001; Hagen (Strüver, 2002); Goldstone T.L, 2011
	Bulk data movement	Goldstone T.L, 2011
Activity monitoring and event management service	Process monitoring; business activity monitor (event and state management); process awareness (business activity monitoring); Event coordination and event management, Process flow control (acknowledging events, trigger execution)	Forrester (Brodie, 2006); Natis, 2001; Linthicum, 2003; Goldstone T.L, 2011
Partner management service	Business process (inter-organizational processes); partner management; Supply chain	Erasala et al., 2003; Forrester (Brodie, 2006); Merkel, 2000
Business level integration service	Process-awareness (support for modeling, optimization and abstraction of business processes); development services (process modeling); Process flow control (describe the processes)	Linthicum, 2003; Puschmann and Alt, 2004; Goldstone T.L, 2011
	Process simulation;	Forrester (Brodie, 2006);
Supporting service	Development; development services (transformation specification and interface development); development tools, extensibility via traditional programming; testability	Natis, 2001; Puschmann and Alt, 2004; Goldstone T.L, 2011; Gorton, 2007
	Supportability, Modifiability	Gorton, 2007
	Administrative and runtime services (distribution, scalability and monitoring); Error handling, run time environment (active listening, event coordination and multi threaded processing), Recoverability, Workload balancing, High performance; Scalability, Performance, Availability (Recoverability, Reliability, Failure handling)	Puschmann and Alt, 2004; Goldstone T.L, 2011; Gorton, 2007
	Flexibility (EAI Topology independence, Platform independence); Portability	Natis, 2001; Puschmann and Alt, 2004; Goldstone T.L, 2011; Gorton, 2007
	Security services; connectivity service (security service); Security services	Natis, 2001; Puschmann and Alt, 2004; Goldstone T.L, 2011
	Simplicity or complexity of tools, legacy and mainframe integration capability, Integration without programming; Ease of integration, Capabilities of off-the-shelf components	Goldstone T.L, 2011; Gorton, 2007

Using information given in Tab. 4, and after the refinement, classification and the extension of the extracted list of integration functionalities and features, we proposed a more comprehensive list of core integration features (Tab. 5). The proposed list of core integration features includes two kinds of

features include Functionalities and Supporting features. Functionalities include Messaging, Persistence, Routing, Service-oriented connectivity, Information-oriented connectivity, Syntactic conversion, Semantic transformation, Transaction management, Business Semantics and metadata, Business rule management, Process management, Bulk data movement, Human workflow management, Activity monitoring and event management, and Partner management. Supporting features also include Process modeling, Process simulation, Development and support, Administrative and runtime, Ease of integration, Flexibility and portability, and Security. Readers would find a brief description for every features in Tab. 5.

As displayed in Tab. 5, we have extended our previous list of functional integration capabilities which presented in Moradi, Bahreininejad (2010) research by regarding two kinds of features include Functionalities and Supporting features. We proposed three new functionalities include Bulk data movement, Business semantics and metadata, and Partner management, along with extending the Process monitoring feature to an extended feature (Activity monitoring and event management feature). Moreover, we have proposed seven new supporting features include Process modeling, Process simulation, Development and support, Administrative and runtime, Ease of integration, and Security. The extended items of Tab. 5 have been highlighted.

Tab. 5: The proposed list of core integration features
(Adapted from Moradi, Bahreininejad (2010) and have been developed in this research)

	Core Integration Feature	Description
Functionalities	Messaging	Support for the data transfer between applications
	Routing	Support for intelligent-based message routing between applications
	Persistence	Support for the logging and warehousing of exchanged data
	Service-Oriented Connectivity	Support for the service-oriented connectivity between applications (share application services and invoking them)
	Information-Oriented Connectivity	Support for the information-oriented connectivity between applications (share and exchange information between applications)
	Syntactic Conversion	Support for the syntactic conversion (adaptation) of exchanged data
	Semantic Transformation	Support for the semantic transformation (semantic mapping) of exchanged information
	Transaction Management	Support for the short-term and long-term transactions
	Business Semantics and Metadata	Support for business semantics as well as metadata (message dictionary) and metadata representation service
	Business Rule Management	Support for the management of business rules and rule engine
	Process Management	Support for the orchestration, coordination and management of fully-automated business processes where the composition of process elements occurs fairly rapid
	Bulk Data Movement	Support for high-performance and bulk data movement between two data sources
	Human Workflow Management	Support for the coordination and management of semi-automated workflows where the composition of process elements occurs in long-term
	Activity Monitoring and Event Management	Support for the monitoring and supervising on business processes (business activity monitoring as well as event and state coordination and management)
Partner Management	Support for inter-enterprise process choreography and coordination as well B2B integration features	

	Core Integration Feature	Description
Supporting features	Process Modeling	Support for modeling, optimization and abstraction of the business processes
	Process Simulation	Support for the simulation of business processes
	Development and Support	Support for the development services such as transformation specification and interface development along with extensibility, modifiability, supportability and testability of integration solution
	Administrative and Runtime	Support for the administrative and runtime services such as distribution, scalability and workload balancing, monitoring, performance and availability (recoverability, reliability and failure handling)
	Ease of Integration	Simplicity or complexity of integration tools through off-the-shelf components to facilitate legacy and mainframe integration and integration without programming as well as support for non-invasive integration
	Flexibility and Portability	Flexibility in functionality and modification along with the portability of integration solution (topology and platform independence)
	Security	Support for the security of integration solution

3.4 The proposed evaluation framework

After proposing an innovative structure for evaluating the enterprise integration middleware technologies in the first part, and recommending the proposed list of enterprise integration middleware technologies and their associated classification in the second part, and suggesting the list of core integration features in the third part, and finally combining the proposed structure with two proposed lists, we would have a comprehensive framework for evaluating the core integration features of enterprise integration middleware technologies. The proposed framework was shown in Tab. 6. The new items of this framework have been highlighted.

The proposed framework offers a new schema for which various enterprise integration middleware technologies were categorized in different classes and were evaluated based on their supporting level for the core integration features' criteria. Core integration features' criteria composed of two sections include the functionalities and supporting features. The proposed framework can be used by information system experts for evaluation and comparison purposes of various integration technologies.

Tab. 6: The proposed comprehensive framework for evaluating the core integration features of enterprise integration middleware technologies
(Adapted from Moradi, Bahreininejad (2010) and have been developed in this research)

		Evaluation Criteria (Core Integration Features)																						
		Functionalities												Supporting Features										
		Messaging	Routing	Persistence	Service-Oriented Connectivity	Information-Oriented Connectivity	Syntactic Conversion	Semantic Transformation	Transaction Management	Business Semantics and Metadata	Business Rule Management	Process Management	Bulk Data Movement	Human Workflow Management	Activity Monitoring and Event Management	Partner Management	Process Modeling	Process Simulation	Development and Support	Administrative and Runtime	Ease of Integration	Flexibility and Portability	Security	
Classification	Integration Technologies																							
Elementary Message Oriented Middleware	Message Oriented Middleware (MOM)																							
	Publish/Subscribe Broker																							
	Remote Procedure Calls (RPC)																							
	Extensible Markup Language (XML)																							
Database Access Technologies	Open Database Connectivity (ODBC)																							
	Java Database Connectivity (JDBC)																							
	Database Gateway																							
Application Access Technologies	Application Adapter																							
	Screen Scraper																							
	Application Programming Interface (API)																							
Service-Oriented Technologies	Web Services																							
	Enterprise Service Bus (ESB)																							

Distributed Object Technologies	Common Object Request Broker Architecture (CORBA)																			
	Common Object Model/ Distributed Common Object Model (COM/ DCOM)																			
	Enterprise JavaBeans (EJB)																			
Data-Oriented Technologies	File Transfer Tools																			
	Data Replication																			
	Extract, Transform and Load (ETL)																			
Information-Oriented Technologies	Virtual Database or Enterprise Information Integration (EII)																			
Transaction-Oriented Technologies	Transaction Processing Monitors (TPM)																			
	Application Server																			
Modern Brokers	Enterprise Application Integration (EAI) Broker																			
	Business Process Management (BPM) Package																			
Modeler and Simulator Technologies	Process Modeling and Simulation Tools																			
B2B Integration Technologies	EDI																			
	Supply Chain Integration Tools																			
	On-line Trading Brokers																			

3.5 Evaluation and verification phase

Finally, we evaluated our framework through an interview with information system experts as well as prepare a semi-structured questionnaire and sending it to a list of information system and integration experts electronically. We received feedback from 25 academics and 12 practical experts. Here are some of the most important feedbacks from the experts:

- Most experts said our proposed list of integration technologies is comprehensive, and it's difficult to add a new item to the proposed list; however, a few number of experts excluded some rows from our proposed list (for instance, file transfer technologies).
- Also, a few number of experts said that ETL tools are a developed version of data replication technologies, and we should regard both technologies as one technology.
- One expert suggested to add a new kind of Data-oriented technologies to our framework. He proposed to add CDI²⁶ hub or MDM²⁷ tools to Data-oriented technologies' class.
- A few number of researchers believed that we should add additional criteria such as organizational issues and managerial issues such as budget, maturity of integration technologies, risks and etc. to the criteria section. Remember that we have developed a new framework to evaluate the core integration features of application integration technologies, and it's not a framework to match the whole integration needs and integration technologies directly. However, it is a good idea to propose a more comprehensive evaluation framework to match the integration needs and the enterprise integration middleware technologies directly in the future researches.

4. Framework Application

Information system practitioners and managers can leverage the proposed framework for the evaluation and comparison purposes of various integration technologies. Here there is a multi-step process to use this framework in the real world situations.

- Practitioners and managers involved in enterprise integration projects must prepare a list of integration needs that should be met by enterprise integration middleware technologies (here addresses as IN).
- These needs should be classified as two different needs: Core Integration Needs (addresses as IN.CIN), and Business and Organizational Needs (addresses as IN.BON). Core Integration Needs (IN.CIN) which addresses technical aspects of integration needs should be extracted from the IN list. Here we would have a list of core integration needs that should be met by enterprise integration middleware technologies.
- Now, use the top section of the proposed framework to choose the Core Integration Features (CIF) which met the Core Integration Needs (IN.CIN).
- After that, regarding the Core Integration Features (CIF), choose one or multiple technologies which met the Core Integration Needs from the left section of the proposed framework, and insert them into a new list, named Enterprise Integration Technologies (EIT).
- Finally, you should re-evaluate and filter your list of Enterprise Integration Technologies (EIT) from business and organizational viewpoint. This could be done using IN.BON list. Choose one or multiple technologies from EIT list which met Business and Organizational Needs (IN.BON) and insert them into the FINAL list of enterprise integration middleware technologies that met your integration needs. The FINAL list would be the right tools to meet your enterprise Integration Needs.

5. Comparison and Research Innovation

In this section, we compare our proposed evaluating framework with two important ones in enterprise integration literature include Themistocleous et al., (2004) and Forrester (Brodie, 2006)) frameworks, as well as our previous framework in this area (Moradi, Bahreininejad, 2010). The first glance to the proposed comprehensive framework, we will find a brand new framework.

Structurally, this framework proposes a new schema which has been enhanced using the structural and conceptual aspects of previous frameworks. Conceptually, the evaluation case of the proposed framework (the list of integration technologies and their associated classifications concept) has adapted from the Themistocleous et al., (2004) framework, and also the concept of its evaluation

²⁶ Customer Data Integration

²⁷ Master Data Management

criteria (functionalities of integration solutions) has adapted from Forrester framework (Brodie, 2006); however, we have developed the structure and content of these two frameworks.

The list of core integration features of the proposed framework is somewhat similar to the Forrester framework (Brodie, 2006), but regarding our new kind of criteria (supporting features), we have developed the structure and content of the Forrester framework.

Moreover, the list of enterprise integration middleware technologies and their associated classification in the proposed framework is fairly similar to the Themistocleous et al., (2004) framework; however, we have introduced some new technologies, and also have classified integration technologies differently.

In our previous framework in this area (Moradi, Bahreininejad, 2010), we had narrowed down the scope of our research, whereas the integration technologies and functional capabilities related to Application and Software Platform levels had been attended, but Business specific level technologies and capabilities such as Modelling tools and process simulation capability had not been considered in its research scope. Furthermore, the explicit inter-enterprise technologies and capabilities such as EDI technology and partner management capability had been excluded from the research scope of the previous framework. Also, the supporting features such as security, scalability, development services and etc. had been excluded from the research scope of the previous framework.

But in our new comprehensive framework, the scope, structure and content of our previous framework has been extended. So this one is a more comprehensive framework as has been explained below:

- In our new framework, various enterprise integration middleware technologies have been classified in different classes and evaluated based on their supporting level for the core integration features' criteria. Core integration features' criteria are composed of two sections includes the functionalities and supporting features. Just like as our previous framework, and also the Forrester framework, functionality is related to the integration functionalities of application integration technologies, but supporting features is related to the supporting features of enterprise integration technologies.
- Furthermore, this framework has developed the evaluation criteria by regarding ten new criteria include Business Semantics and Metadata, Bulk Data Movement, Partner Management, Process Modeling, Process Simulation, Development and Support, Administrative and Runtime, Ease of Integration, Flexibility and Portability, and Security as well as extending the Process monitoring criterion to new Activity Monitoring and Event Management criterion.
- Moreover, the new comprehensive framework has extended the evaluation case by regarding four brand new classes and four new technologies include Process Modeling and Simulation Tools (Modeler and Simulator Technologies) and B2B integration technologies (EDI, Supply Chain Integration Tools and On-line Trading Brokers) and Information-oriented technologies (Virtual Database or EII) along with removing the class of file transfer technologies and merging it with the Data-oriented technologies' class (file transfer technologies, data replication and ETL).

6. Conclusion

In this paper, we proposed a new comprehensive framework for evaluating the core integration features of enterprise integration middleware technologies based on our previous paper in this area, which simplify the process of evaluating the core integration features of integration technologies and solutions. The proposed comprehensive framework for evaluating the enterprise integration middleware technologies has been enhanced using the structural and conceptual aspects of previous frameworks; however, we have developed the structure and content of them By proposing 22 evaluation criteria, 11 classifications, and 27 technologies. Information system experts can leverage the proposed framework for the evaluation and comparison purposes of various enterprise integration middleware technologies. However, regarding our research limitations, they should re-evaluate integration technologies from organizational and business aspects independently.

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JEL: M15