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Novel taxonomy for application integration

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Abstract *One of the main motivations associated with the adoption of electronic commerce (e-commerce) is the integration and automation of business processes. Yet, for many years the integration of systems has been a barrier to business process automation. However, a new generation of software called application integration (AI) efficiently addresses integration problems and leads to more flexible and maintainable solutions. AI incorporates functionality from disparate applications through a diversity of integration technologies. Regardless, confusion surrounding terminology in the integration area has led to a debate regarding the capabilities of AI, as each term proposes a different range of AI technologies. Therefore, there appears a clear need to clarify this confusion. In doing so, a novel taxonomy is proposed, which is based on the critical analysis and evaluation of existing case studies extrapolated from the AI literature. The proposed taxonomy separates AI into intra-organisational AI, hybrid AI and inter-organisational AI. The novelty of the taxonomy centres on the synthesis of a comprehensive set of systems that efficiently describe the range of AI technology in terms of application. In doing so, the taxonomy presented will allow developers and integrators to navigate better through the portfolio of integration technologies and therefore better understand the integration area. The proposed taxonomy might also be used as a tool for decision making.*

Introduction: electronic commerce revolution and the need for integration

Electronic commerce (e-commerce) refers to conducting business electronically using computers and networks, and focuses on the integration and automation of business processes (Kalakota and Robinson, 1999). Doukidis *et al.* (1998) suggest e-commerce provides access to global markets through the Internet and leads to competitive advantages as it improves sales channels, and simplifies and automates transactions. In addition, it achieves cost reduction and user satisfaction, and improves relationships with customers and suppliers. The advantages that e-commerce offers can be transacted in the redesign of business practices, strategies and models (Timmers, 1998). As a result, a tremendous expansion of e-commerce applications around the world has resulted in revenues of billions of dollars per year for those companies involved.

However, during recent years a number of e-commerce enabled companies have failed (e.g. http://www.e-toy.com), with Hooft and Stegwee (2001)

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reporting a lack of management support, insufficient budgets and cultural issues as the main reasons for this failure. In addition, Bhatt and Emdad (2001) and Kalakota (2000) suggest that integration plays a critical role for the success of e-commerce applications. Linthicum (2000) and Morgenthal and La Forge (2000) report that e-commerce applications are not integrated solutions but have to be incorporated with back-office systems to support real-time transactions, automate and integrate business processes. As a result, there is a need to unify e-commerce solutions with existing IT infrastructures, allowing enterprises to gain e-commerce advantages. The need for integration has led much literature to separate e-commerce solutions into integrated and non-integrated applications. Based on this categorisation the term e-business was introduced to describe integrated e-commerce applications, with Kalakota and Robinson (1999) suggesting that e-business solutions achieve structural transformation and are based on flexible and manageable architectures. Isakowitz *et al.* (1998) and Pant and Ravichandran (2001) claim that e-business systems allow transactions to be conducted in an integrated way by removing constraints imposed by diverse systems. However, Linthicum (2000) reports that the term e-business refers to business to business (B2B) applications, whereas e-commerce tends to refer to business to consumer (B2C) applications.

During the last decades many companies have used electronic data interchange (EDI) technology and value added networks (VAN) to exchange their business documents in an integrated way (Emmelhainz, 1993). However, the complexity and high cost of EDI as well as the emergence of the Internet as a global platform for e-business led organisations to adopt open standards such as extensible markup language (XML) to facilitate their transactions and achieve integration. Linthicum (2000) claims that although XML supports the integration of Internet based transactions, it cannot address all integration problems, as many transactions are not run over the Internet but on back-office systems. In addition, organisations consist of a set of complex, incompatible information systems with diverse information formats, heterogeneous computing platforms and various programming models that require technologies to piece together all these systems. In attempting to bridge technology created gaps, an emerging generation of software called application integration (AI) incorporates functionality from disparate systems and leads to flexible and maintainable solutions (Zahavi, 1999). Application integration allows enterprises to piece together their inter-organisational (e.g. enterprise resource planning systems) and intra-organisational systems (e.g. capacity planning), and thus maximise their benefits from the use of e-commerce and e-business applications. The authors of this paper discuss the theoretical grounding of this new technology (AI), which results in the presentation of a novel taxonomy for e-business and application integration.

Theoretical foundations of application integration

A diversity of confusing terms such as enterprise application integration (EAI) (Brown, 2000), application integration (AI) (Sprott, 2000), systems integration

(SI) (Hasselbring, 2000), value chain integration (VCI) (Yang and Papazoglou, 2000), supply chain integration (SCI) (Linthicum, 1999a), extended business integration (EBI) (Markus, 2000) and e-business integration (e-business I) (Linthicum, 2000) were presented in the literature to define the information system integration area. In attempting to navigate through this confusion, Themistocleous *et al.* (2000) distinguished much of this terminology. In the context of this paper, the term application integration (AI) is adopted to refer to the integration area.

AI seeks to address more effectively the need to integrate both intra- and inter-organisational systems by incorporating functionality from disparate applications. It combines diverse technologies such as adapters and application servers to support data, objects/components and processes incorporation as well as custom applications, packaged systems and e-business solutions integration. Linthicum (1999a) suggests that AI enables information sharing and supports reusable business processes through integration technologies (e.g. message brokers).

Application integration efficiently incorporates systems by connecting them to a common integrated infrastructure, thus eliminating the changes to application codes. Therefore, AI solutions reduce integration time and lead to more flexible, manageable and maintainable solutions. Additionally, AI allows easier migration to new technologies as it comforms to common standards (XML, CORBA). A significant business benefit of AI is the reduction of overall integration costs due to the reduction of both integration time and maintenance costs. Ruh *et al.* (2000) claim that an integrated infrastructure allows companies to improve their performance, increase their productivity and provide better services for their customers, as a result improving their relationships with their clients. Likewise, AI supports strengthened supply chains and improves the relationships between organisations and suppliers.

However, a number of barriers prevent the widespread adoption of AI, as many companies consist of a set of incompatible information systems, often with heterogeneous computing platforms, and various programming models. There is also complexity of existing information systems, which in many cases have fixed and rigid structures for messages, interfaces and databases (Ruh *et al.*, 2000). Thus, integration becomes much more difficult and complex than software development since integration requirements need to be considered along with constraints and requirements of existing systems (Zahavi, 1999).

Another barrier to AI is the product choice and the maturity of integration technologies. This is further complicated with developers needing to combine a variety of technologies and products to achieve an acceptable degree of integration. Application integration comprises diverse integration technologies, with each focusing on different integration domains. As a result, Duke *et al.* (1999) suggest that there is no single technology that solves all integration problems. AI requires a vast amount of technical expertise and a complex set of skills, but there remains a lack of skilled staff familiar with AI. Moreover, a shortage of skilled staff has led to high salaries for integrators,

which translates into higher project costs (Themistocleous and Irani, 2001a). Clearly, the cost of integration could be seen as a barrier to AI adoption, as most companies consider integration as a major investment. A further barrier could be organisational culture, as previous data integration failures may have created negative perceptions of chance which need to be overcome.

Application integration: a novel taxonomy for classifying types of systems

Confusing terminology in the integration area has led to a topical debate regarding the types of information systems that can be integrated through AI, as each term proposes the incorporation of different types of systems (e.g. ERP-to-legacy systems integration). For example, Grimson *et al.* (2000) suggest that the term enterprise application integration (EAI) refers to the integration of enterprise resource planning (ERP) systems (e.g. ERP to ERP), while Duke *et al.* (1999) claim it supports the incorporation of all packaged applications. In contrast, Ruh *et al.* (2000) report that EAI does not only piece together packaged systems but also intra-organisational solutions, while Zahavi (1999) claims that it supports both enterprise and cross-enterprise application incorporation. In attempting to navigate through the problem domain, Themistocleous *et al.* (2000) have attempted to overcome the confusion surrounding the application integration terminology by evaluating the various definitions and suggesting the need to develop taxonomies.

Clearly, there is a need to better clarify and define the dimensions (range) of AI technology in terms of types of applications that are pieced together through AI. In addressing the aforementioned need, a novel taxonomy is proposed by the authors, which attempts to clarify this confusion. The taxonomy is based on the critical analysis and evaluation of the limited existing case studies and associated literature on AI. The novelty of the taxonomy focuses on the synthesis (development) of a comprehensive set of systems that efficiently describe the dimensions (range) of AI applications. The proposed taxonomy will allow managers and developers to better understand the integration area, and can be used as a tool for decision making. Based on this novel taxonomy, managers and business analysts will be able to interpret and realise the capabilities of AI. As a result, understanding that AI can be enabled as a strategy to piece together both enterprise and cross-enterprise applications and, therefore, AI lead to the development of an integrated infrastructure that supports intra-organisational and inter-organisational applications.

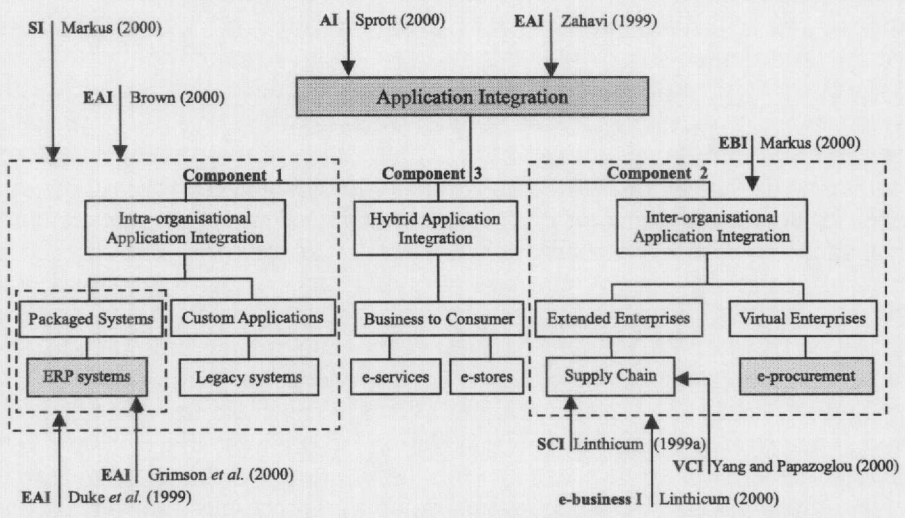
Normative literature classifies information systems into intra-organisational and inter-organisational. Kaufman (1996) and Bytheway and Dhillon (1996) report that inter-organisational systems (IOS) are networks of systems that allow businesses to share information and interact electronically across organisational boundaries. In contrast, intra-organisational solutions exchange data at an enterprise level (Emmelhainz, 1993). It is therefore proposed that application integration might follow this classification. In support of this, Zahavi (1999) suggests that AI incorporates enterprise and cross-enterprise

applications, and thus resulted in integrated intra-organisational and inter-organisational systems. Hence, the authors propose a taxonomy that separates AI into intra-organisational and inter-organisational AI. In addition, a new sub-category called hybrid AI is also proposed and integrated into the proposed taxonomy to describe e-commerce applications that function as intra-organisational and/or inter-organisational AI systems. Figure 1 demonstrates the proposed novel taxonomy.

The taxonomy presented classifies AI into intra-organisational, inter-organisational and hybrid AI. On a second level, intra-organisational AI is divided into packaged systems and custom applications integration where hybrid AI into B2C integration. Inter-organisational AI is further categorised into extended and virtual enterprise integration. The lowest level in Figure 1 presents exemplar applications for each category (e.g. e-stores, e-procurement).

Component 1: intra-organisational AI

Packaged and custom systems are classified as intra-organisational applications and thus form subcategories of intra-organisational AI (Handfield and Nichols, 1999). A custom application (e.g. legacy systems) is designed to address specific point problems and can therefore not be adopted by another company. Brodie and Stonebraker (1995) report that custom systems such as legacy were developed to operate in a particular way and therefore, resist modification and evolution to meet business requirements. Most legacy systems follow a monolithic model (Zahavi, 1999) in which data, logic and interfaces are not separated but are built together (Bernus *et al.*, 1996). In



Abbreviation	Term
AI	Application Integration
EAI	Enterprise Application Integration
e-business I	e-business Integration
EBI	Extended Business Integration

Abbreviation	Term
SCI	Supply Chain Integration
SI	Systems Integration
VCI	Value Chain Integration

Figure 1.
Novel taxonomy for application integration

contrast to custom systems, packaged solutions follow a three-tier architecture model in which data are separated from business logic and interfaces and can therefore be easily updated or modified (Serain, 1999; Wijegunarate and Fernandez, 1998).

In addition, packaged systems like ERP solutions were based on generic business requirements and processes, and not on the requirements of a specific organisation (Holland and Light, 1999; Holland *et al.*, 1999; Loinsky, 1995). Thus, the same packaged system (e.g. SAP) is adopted by many enterprises, without much customisation. However, Davenport (1998) reports that packaged systems do not allow much customisation, and thus organisations have to change their business processes and strategy to fit packaged systems.

Case studies reported by Edwards and Newing (2000) demonstrate that application integration efficiently supports the integration of ERP systems and custom applications using a diversity of integration technologies such as database oriented middleware (e.g. ODBC), messaging technologies (e.g. XML, message brokers), transaction oriented technologies (e.g. application servers), distributed objects (e.g. CORBA) and interface oriented technologies (e.g. adapters, wrappers) (Linthicum, 1999a; Themistocleous and Irani, 2001b). However, both packaged and custom systems have different types of integration problems and therefore focus on different integration technologies[1]. As a result, packaged and custom systems can form two different subcategories of intra-organisational AI.

Component 2: inter-organisational AI

Inter-organisational integration seeks to incorporate cross-enterprise business processes and systems such as supply chains (Brown, 2000). E-business solutions are part of this subcategory, with Kalakota and Robinson (1999) classifying them as inter-organisational applications. Linthicum (2000) suggests that AI incorporates e-business through the same category of technologies (e.g. message brokers, adapters, XML) which support intra-organisational integration. Much literature (Brown, 2000; Loinsky, 1995) classifies integrated applications according to the degree (loose, tight) of integration achieved. This categorisation is important, as companies tend to follow the one or the other degree of integration when incorporating their e-business systems. According to Helm (1999), loose integration is usually followed by loosely coupled trading partners. These partnerships select loose integration to simply share or exchange information electronically. Puschmann and Alt (2001) report that loosely integration is correlated with asynchronous communication (Duke *et al.*, 1999; Wijegunarate and Fernandez, 1998). The type of communication determines dependencies among two applications and influences the processing sequence of the involved applications (Serain, 1999). In asynchronous communication, applications communicate over time without having to wait for target application to receive and process the data, and reply to the source application (Morgenthal and La Forge, 2000). In general, loose integration is adopted by organisations that are reluctant to tightly integrate

their systems over cross-enterprise networks or there is no need to develop a tight integration model, which results in the development of a common cross-enterprise integration infrastructure (Helm, 1999).

Tightly integrated applications are characterised by a higher degree of process dependency. According to Puschmann and Alt (2001), tightly integrated applications follow synchronous communication (Serain, 1999), with the sender application pausing its operations and waiting for the receiver to execute senders' requests or process the data requested and reply (Ruh *et al.*, 2000). This type of communication is accomplished in a co-ordinate manner, which may lead integrated applications to failure if one system is unable to execute a process. In this case, all partners fail because they all participate in the same logical business process (Kalakota, 2000; Linthicum, 1999b). Helm (1999) suggests that organisations develop a homogeneous inter-organisational IT infrastructure when selecting tight integration since such infrastructures allow them to increase their efficiency and function as a "single" (virtual) enterprise. Based on the degree (loose, tight) of integration, Helm (1999) therefore proposed three scenarios for e-business integration, which include:

(1) enabling extended enterprises;

(2) enabling virtual enterprises; and

(3) e-commerce AI.

The first scenario, enabling extended enterprises, refers to loosely integrated e-business applications (e.g. e-supply chain management) where the need for the development of a homogeneous cross-enterprise integrated infrastructure is not too important. In this case, organisations extend their business activities through e-business solutions, and try loosely to incorporate these applications with external partners (Helm, 1999; Riggins and Rhee, 1998). In this scenario, collaborators exchange data but do not share common business processes.

The scenario enabling virtual enterprises refers to tightly integrated e-business applications where integration is very important, with a number of enterprises sharing common data and processes. In this case, there is an attempt to function as one (virtual) organisation.

In many cases to support more efficient common processes, real-time information is needed. As a result, a high degree of incorporation is required between back-end systems and e-business solutions to support real-time information. Hence, the first two scenarios are adopted to classify inter-organisational AI further as they both deal with the integration of e-business solutions. However, the differences that exist between these two scenarios are presented in Table I, and have led the authors to separate them in two different categories (extended enterprises and virtual enterprises).

Component 3: hybrid AI

According to Helm (1999), the third scenario, e-commerce AI, presents no challenge for integration among business partners. The reason for this is that it

	Reference
Loose integration	
Focuses on exchanging/sharing data among partners	Kalakota and Robinon (1999)
Low degree of process dependency	Loinsky (1995)
Low degree of integration	Brown (2000)
The development of a homogeneous, integrated, cross-enterprise infrastructure is not important	Helm (1999)
Asynchronous communication	Puschmann and Alt (2001)
Tight integration	
Focuses on integrating cross-enterprise business processes and systems	Themistocleous and Irani (2001b)
Highest degree of process dependency	Kalakota and Robinson (1999)
High degree of integration	Brown (2000)
The development of a homogeneous, integrated, cross-enterprise infrastructure is important	Helm (1999)
Synchronous communication	Puschmann and Alt (2001)

Table I.
Loose and tight integration

focuses on B2C solutions and therefore there are no business partners involved in these types of systems. However, literature (Electronic Commerce Awareness, 2001; Bakos, 1998; Lee, 1998; Lohse and Spiller, 1998; Riggins and Rhee, 1998; Timmers, 1999) supports that in some cases (e.g. e-stores) there is a need to integrate B2C applications with other inter-organisational solutions (e.g. suppliers, distributors, banks, etc). The reason for this is that inter-organisational systems have an important role in supporting the functionality of an e-commerce application. As a result, some business to consumer applications function as inter-organisational systems while others function as intra-organisational applications.

The main users of B2C applications include companies that owns the application (application service providers, shop provider) and Internet users (consumers) that communicate with these applications (Doukidis *et al.*, 1998). In some applications (e.g. e-services) consumers subscribe once (by paying, electronically or not, a fixed amount of money to a bank) and then use the system for a specific time period (e.g. one year). During this period, the owner of the B2C application provides services to the customer without the involvement of an external entity (e.g. supplier). Thus, there is no need to integrate this type of system with external partners/companies, as there are no external companies. Hence, this type of system functions like an intra-organisational application. However, other types of B2C applications function like extended enterprises or virtual enterprises. For example, many e-store applications require integration across enterprises, as they incorporate banks', suppliers' and distributors' systems. Hence, the proposed taxonomy adopts a new sub-category (hybrid AI) at the same level as intra- and inter-organisational AI and includes B2C AI. Table II summarises the characteristics of each category of the proposed taxonomy.

Category	Characteristics	Reference
Intra-organisational AI	Integrates enterprise applications	Brown (2000), Loinsky (1995)
	Integrates packaged and custom systems	Edwards and Newing (2000), Ruh *et al.* (2000)
	No transactions with external users or partners	Themistocleous and Irani (2000), Helm (1999)
Hybrid AI	Integrated B2C applications with IT infrastructure	Themistocleous and Irani (2000)
	Internet users purchase products or services Hybrid AI applications support the transactions by integrating internal systems and/or external partners	Kalakota and Robinson (1999), Doukidis *et al.* (1998)
Inter-organisational AI	Integrates cross-enterprise applications with IT infrastructure	Linthicum (2000), Zahavi (1999)
	Integrates B2B applications	Markus (2000), Morgenthal and La Forge (2000)
	Based on the degree (loose, tight) of integration it is separated: extended enterprises (loose integration) virtual enterprises (tight integration)	Helm (1999), Puschmann and Alt (2001)

Table II.
Characteristics of the sub-categories of the proposed taxanomy

Conclusions

The value from the use of e-commerce and e-business applications comes when companies integrate all disparate applications in a way that supports efficient business processes across the whole value chain. Initially organisations attempted to achieve integration through EDI but the cost of implementation and the complexity has led them to search for flexible and maintainable ways to piece together their systems. Organisations are increasingly turning to AI technology to develop an integrated infrastructure by incorporating functionality from disparate applications. AI helps organisations gain control of their inter- and intra-organisational processes and, in doing so, address integration problems such as custom, packaged and e-business applications integration. It combines a diversity of integration technologies to provide flexible and maintainable solutions.

Confusing terminology in the integration area has led to a debate regarding the capabilities of AI, as each term proposes a different range of AI application. As a result, a need has been presented to define the range of AI technologies in terms of applications, as well as to categorise the types of systems that can be integrated through AI. In doing so, the authors of this paper have presented a novel taxonomy that seeks to allow integrators to better navigate, categorise and explain the types of applications that can be integrated. The proposed classification separates applications into three main subcategories:

(1) intra-organisational AI;

(2) hybrid AI; and

(3) inter-organisational AI.

The first subcategory includes the integration of intra-organisational systems such as packaged and custom systems. The second subcategory describes the integration of business to consumer applications. The applications of this subcategory are characterised as hybrid, as in some cases these applications function as intra-organisational AI and in others as inter-organisational applications. The last subcategory includes B2B applications integration, and it is further classified according to the degree (loose, tight) of integration.

Note

1. For instance, screen wrappers are used to extract data and objects and support custom systems integration where packaged solutions focus on application programming interfaces (APs) to achieve data and object integration.

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