A FRAMEWORK FOR ASSESSMENT OF ENTERPRISE INTEGRATION APPROACHES AND TECHNOLOGIES

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Abstract: Enterprise integration is the study of an organization, its business processes, and resources, understanding how they are related to each other and determining the enterprise structure so as to efficiently and effectively execute the enterprise goals. There are many separate research streams that have developed theories, approaches, and technologies for integrating the enterprise. There seems to be little sharing of concepts across disciplines or consensus on the topic of enterprise integration. Moreover, what is meant by the term 'integration' is poorly defined. In this article an enterprise integration framework is presented to bring together the divergent views of enterprise integration so that how they are related to each other can be understood. The enterprise integration framework defines five levels of the enterprise system to define the integration types encountered at each level. The five levels are organization, process, application, data, and network. The enterprise integration framework is used to analyse the many approaches used by different disciplines toward enterprise integration. The analysis identifies gaps for further research.

1 INTRODUCTION

Integration across the enterprise is one of the most significant issues facing today's organizations. Over the years, both business and government entities have developed many management and technology systems that address the needs of local organizational units. Example local systems include accounting systems, inventory control systems, and human resource systems among many others. Historically, these systems were designed, built, and optimized to solve the local needs. There is little regard for how the local system would fit into the entire enterprise. These local systems utilize various data representation formats, have different data semantics, are built using different programming languages, and are launched on various hardware platforms. The problem of how to integrate these heterogeneous systems has instigated a significant amount of research work.

There are many separate research streams that attempt to address enterprise integration. There are approaches developed within the database research [1], information systems development [2], software engineering [4], agent-based systems [5], production engineering [6], organizational theory and design [7], and the general business communities [8]. There seems to be little sharing of concepts across disciplines or consensus on the topic of enterprise integration. In some work the enterprise denotes information systems that can be integrated via technical approaches. Others view the enterprise from an organizational approach and propose various coordination mechanisms and management tools for integration. Moreover, what is meant by the term 'integration' is poorly defined. The lack of an agreed upon definition of integration is unfortunate because the volume of research in enterprise integration as well as the amount of money budgeted to achieve enterprise integration indicates it is a significant challenge that companies view as important. It appears that the literature in each of

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these fields has not benefited from cross fertilization in the ongoing discourse on integration. This suggests a redundant and inefficient use of intellectual resources and that opportunities for synergy may have been overlooked.

In this paper an enterprise integration framework is developed to coalesce the large but disparate body of research on enterprise integration. The goal of the framework is to extract the relationships between the various integration approaches and show how they complement each other. In this way the issues embodying enterprise integration and strategies for researching enterprise integration can be better understood. Using the framework we analyze to what extent the various integration approaches meet the goals of enterprise integration. Finally, from the framework we identify further areas for research.

1.1 Enterprise Integration Motivation

A primary motivation for research in enterprise integration is the serious economic ramifications that result from failure to adequately address integration. The NIST Strategic Planning and Economic Assessment Office studied interoperability in the US automotive supply chain and estimated a yearly one billion dollars in cost due to poor interoperability [10]. In a study conducted by Frohlich and Westbrook [11] they found a strong correlation between supply chain integration and performance. These studies and others suggest higher levels of supply chain integration lead to higher levels of performance.

One of the largest software markets is enterprise resource planning (ERP) systems. ERP systems have been one of the leading software markets for the past several years and have attracted much attention in industry as well academia. The goal of ERP is to integrate the enterprise by installing a single monolithic system; i.e. the ERP system. ERP is a single vendor solution and thus interoperability problems are in theory avoided. In practice, while ERP replaces the many independent information systems companies operated; these same companies have found they still must maintain other applications, which must be integrated with the ERP system. The complexity of ERP systems due to sheer size and scope of automation means that many companies fail to realize the promised benefits of integration [12].

In the software engineering domain, integration is also becoming increasingly important to newer paradigms of component-based software development. Software design today promotes the utilization of reusable components that are assembled together to build applications. Component-based software approaches such as DCOM, .Net, and Enterprise Java Beans all are based on the construction of distributed applications through the coding and assembly of components [13]. Assembly of these components is an integration problem, which is repeatedly in search of some measure of stability and standardization. Researchers are attempting to extend this paradigm to higher levels of granularity of subsystems.

2 ENTERPRISE INTEGRATION FRAMEWORK

An enterprise integration framework would enable organizations to determine the best integration strategy to adopt, how to allocate resources to the integration project, how to manage the integration, how to implement the integration, and how to continuously maintain and update the integration strategy.

2.1 Enterprise Integration Definitions

Enterprise integration is the study of an organization, its business processes and resources, so that relationships may be understood and determining the enterprise structure so as to efficiently and effectively execute the enterprise goals. Enterprise integration falls within enterprise engineering, which has recently emerged as a new discipline that embodies the knowledge, principles, and practices having to do with the analysis, design, implementation, and operation of an enterprise [4].

An examination of definitions for enterprise integration reveals there is little consensus of what integration entails. Batini, Lenzerini, and Navathe [1] focus on the limited but important aspect of data schema integration, which they define as, “the activity of integrating the schemas of existing or proposed databases into a global, unified schema”. Vernadat (1996) argues that enterprise integration should emphasize “business integration, i.e., understanding the way business processes and enterprise policies are structured and coordinated in the enterprise, how they relate to one another and how they can be efficiently executed using the enterprise means depending on the availability of internal or external enterprise objects or conditions. In the organizational science literature integration is defined as overcoming the functional differentiation that occurs when companies decompose themselves into smaller more specialized organizational units that are easier to manage [17]. Perhaps it is Kosanke et al. [16] that have best realized that the term

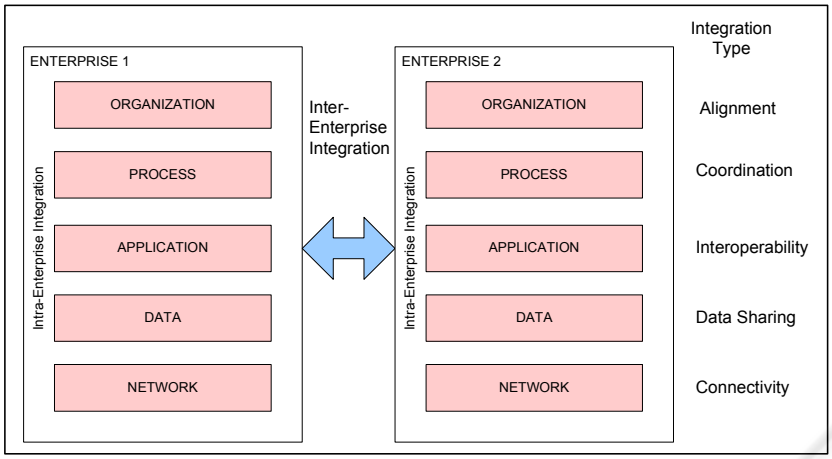

Figure 1: Enterprise Integration Framework

enterprise integration has evolved to encompass several earlier terms such as systems integration of computer networks, application integration of business applications, and business integration of process networks. We have identified four distinct concerns leading to a related set of four research issues to be explored in this research.

Approaches to integrate the enterprise are as varied as the definitions for enterprise integration. There are:

(1) Data integration approaches – Data integration approaches attempt to integrate the data that all the enterprise's systems access [1]. Enterprise database development marks the beginning of enterprise integration approaches. One approach is a global shared data model that all systems access.

(2) Middleware approaches – Middleware is software that resides between the applications and the underlying operating systems, networks, protocol stacks, and hardware [8]. Middleware lets applications interoperate in a distributed environment. There are many middleware technologies. Ruh et al. [18] identify five types of middleware in the market today; procedure calls, database access middleware, message oriented middleware, distributed object technology, and transaction processing monitors.

(3) Process integration or ERP – Enterprise Resource Planning (ERP) systems are large and complex software applications that automate business processes. These systems grew out of persistent approaches to integrate related applications for manufacturing or other business processes. The goal of ERP is to integrate the information flows throughout the value chain within a company thus driving greater efficiency and improved services [17, 26].

(4) Organizational approaches – Organizational theory prescribes mechanisms for coordination of work as a means of integration. Galbraith [17] discusses how the organization uses rules and procedures as coordination mechanisms. Today, researchers describe coordination as a theory in itself and define coordination as the "management of the dependencies that arise between business tasks" [19]. These relationships and the way they can be refined, redesigned or obliterated are the focus of both incremental and radical approaches to managing organizational processes [20] .

(5) Cross-functional teams are a key approach of achieving unity of effort among the sub-units of an organization and thereby achieving integration especially in manufacturing firms for product development [22]. There are detractors of the prevailing approach of cross-functional teams. Sutherland [16] argues that cross-functional teams solve communication problems but whether it leads to integration is left to chance.

(6) Ontological approaches – Ontologies are the name given to context-specific terms and their relationships to formalize the semantics of a communication [22].

(7) Standardization – Standardization has been a general strategy in many of the aforementioned integrative approaches. Akkermans and Van der Hoorst [23] present a typology of standardization mechanisms of coercive standardization (Euro conversion), collaborative standardization either hierarchically ordered (telephony) or voluntary (HTML), consortium-lead (Unix, CORBA), and competitive (MS Windows or Macintosh). Standardization can be argued favourably according to transaction cost theory, which states that standardization lowers communication costs and allows for economies of scale. Standardization is

most appropriate for the slow-changing infrastructure elements such as the network and application levels. It is not appropriate for fast-changing applications. It is a goal of inter-organizational integration as well.

2.2 Framework

We start with a working definition of enterprise integration as: Enterprise integration is the linking together of systems, processes, and organizational units so that the separate parts can act together as a single whole. To this end enterprise integration involves the connection of systems, sharing of data, interoperation of applications, and coordination of business processes. A conceptual framework is presented to decompose the enterprise to reveal and define the integration types so they can be better understood. Figure 1 shows five levels of an enterprise system and the integration types at each level. The five levels are network, data, application, process, and organization levels. Each level contains objects that are more abstract than those below. Level one, the lowest enterprise level, is the network level. At this level the integration issue is the physical heterogeneity of the hardware, machines, devices, and their operating systems found in a physical network. The integration goal at the network level is connectivity defined as the linkages between systems, applications, and modules. Level two, the data level, provides the facts the enterprise system utilizes to complete its business functions. The integration goal is data-sharing where two or more sub-systems or organizational units exchange data with each other. Data-sharing must address the data schema diversity problems described by [1], which can be subdivided into: (i)different perspectives due to the local definitions of concepts for the same or similar concepts; (ii)equivalence among constructs that can be used to represent the same data; and (iii)inter-schema properties that arise when the objects in one schema are related to objects in a second schema. Level three, the application level, describes the systems used by the business. The integration goal is interoperability, which is the ability of one software application to access/use data generated by another software system. Level four, the process level, describes the sequence of tasks conducted in order to produce an output. The problem of task dependencies occurs at this level. The integration type called coordination addresses the problem. Coordination has been defined as the "management of the dependencies that arise between business tasks" [19]. Level five, the level of organizational design, addresses alignment, the way that the three key elements of business strategy, organizational design strategy and information systems strategy must all be aligned with one another. A change in any of these elements requires an adjustment in the others. Thus alignment is the integration task at this level of analysis.

The enterprise integration framework illustrated in Figure 1 unites the many different perspectives of enterprise integration identified in the literature review. For example, middleware approaches focus on interoperability at the application level, database approaches on the data level, and cross-functional teams at the process level. Enterprise integration within a single company implies alignment within and between the different levels into a cohesive enterprise system. Inter-enterprise integration can occur at any level.

2.3 Definition of Enterprise Integration Characteristics

The enterprise integration framework defines individual integration types. When all these integration types are present then enterprise integration is realized. In addition to definition of the integration types it is necessary to define the characteristics of enterprise integration for further distinction between different integration approaches. In this section, drawing upon the literature, a set of integration characteristics is defined.

Reconfigurable – The integrative approach should be reconfigurable so that the integrated system can accommodate changes in organizational structure [15].

Scalable – The integrative approach should be scalable, where scalability is defined as the ability of a system to maintain performance as the size of the system grows or the demand for service from the system increases [24].

Lead-time – The lead-time to establish an integrative connection is important for how adaptable the integrative approach is.

Transparent – The use of the integrative approach should largely be transparent to the users. Many systems are distributed, integrative technologies are often used to hide the distribution [3].

Synchronous/Asynchronous – Whether the communication of information in the system is synchronous or asynchronous. Synchronous communication requires the sender of a request to wait until a reply is received before continuing to process. It needs to wait for the message to be received to continue processing. Asynchronous communication allows the sender to continue processing after the message is sent. Synchronous communication implies a higher degree of

coordination between sender and receiver and thus a high level of coupling [18]. Asynchronous requires less coordination since the sender can continue processing without a response. Within the two categories there are several protocols for realizing that type of communication.

Semantics/Syntax – It is important for the integrative approach to not only let systems share data through definition of acceptable formats (i.e. syntax) but the systems must also be able to understand the shared data (i.e. semantics) [25].

Direction – Integration can be primarily vertical oriented or horizontal oriented [34, 57]. Vertical integration is between levels of a hierarchy and horizontal integration is between peers in the hierarchy.

Degree of centralization/decentralization – Whether the integrative approach is based on a centralization of control or a decentralized structure. The approach should match the organizational structure [26].

Autonomy – Whether the integrative approach allows autonomous selection of systems by the various organizational units or if they must adhere to a limited technology selection. Oftentimes, there is a conflict between maintaining autonomy versus the requirements of integration [3].

Coupling Level – The coupling of the system components, subsystems, or modules through integration should be low. Coupling is defined as the impact changing one component will have on other components. In highly coupled systems changing one component will affect other components. Such high coupling is generally undesirable because it is more difficult to adapt to changing organizational needs and leads to high maintenance costs [9].

3 ASSESSMENT OF INTEGRATION APPROACHES

In this section we discuss the many integration approaches. The enterprise integration framework is used to classify the approaches.

Connectivity at the network level, while not completely eliminated as a problem, has largely been solved. Today, organizations have access to a reliable and extensive network infrastructure. The network infrastructure can transmit voice, data, and multi-media through wired and wireless connections. Integration of the communications through the network is accomplished through protocols that define the message format. As a consequence, for most enterprises, connecting their systems is not a problem.

Data-sharing has received a tremendous amount of attention and continues to be an integration issue for many organizations. One approach is to define a global, unified data schema for the entire organization. Developing a single data model within an organization is often difficult and very costly; to obtain the consensus for a global data model between organizations is even more difficult. A problem in today's business environment is the boundaries and nature of the enterprise is constantly changing so the data model would have to also change. However, the global data model is not easily changed.

Middleware and Enterprise Application Integration (EAI) software are the primary approaches to achieving interoperability between applications. There are many different middleware products with different characteristics so a full exposition should treat each one separately. Here we draw a few main observations. Middleware is intended primarily for decentralized architectures and only addresses the syntax of the communication not the semantics. Strengths of middleware are they tend to be highly scalable, transparent, and reconfigurable. The lead-time to establish a connection between two subsystems is dependent on the middleware used and on the subsystem. Most middleware uses interface definition language (IDL) for each application. For popular applications the IDL is readily available. But for other systems such as legacy systems, the IDL must be developed. Overall, middleware and EAI have been found very useful for enabling interoperation between distributed and heterogeneous systems [26].

Enterprises use both technology and organizational techniques to coordinate their business processes. Early work described various coordination mechanisms organizations could use to coordinate work. The mechanisms included using rules and procedures, mutual adjustment by employees, direct supervision, and standardization of work activities. The need to deliver enterprise integration has instigated a resurgence in research on coordination [6]. These authors have developed enhanced modeling tools and taxonomies for discovering and representing dependencies in enterprise systems and then for specifying coordination mechanisms. The organizational approaches have been used in small, medium-sized, and large organizations so they are scalable. They also support reconfigurability of business processes and systems. The lead-time for installing and/or changing the coordination mechanisms is a subject of change management. The coordination mechanisms are used in both decentralized and centralized organizations.

4 ISSUES

The framework highlights several outstanding issues that require further research.

4.1 Complexity

As enterprise systems become more integrated they also tend to become more complex. Complexity arises from not only the size of the system but also from the interrelationships of the system components and the emergent behavior that cannot be predicted from the individual system components [27]. The reason integration increases complexity is that as a system becomes more integrated the behavior of one component is more likely to influence the behavior of other components. The result is behavior that is often unpredictable. For example, in a supply-chain the integration of the companies leads to the bull-whip effect in which a small disturbance in demand is greatly exaggerated at the other end of the supply chain [28]. Some may view the increased complexity as a negative outcome. However, there is a reason for building complex systems. Complexity is the trade-off for greater performance. The issue is to determine the integration strategy that results in the desired level of performance without generating an excessively complex structure. We postulate that many organizations have excess complexity that does not contribute to improved performance.

4.2 Measurement

The design, analysis, improvement, and management of a system require the definition of desired system properties and measures to quantify those properties. More formally, measurement is the assignment of numbers to attributes of an artifact according to some procedure so that certain properties and relationships are preserved [29]. The definition of measures has been performed in the business community, manufacturing system community, and software engineering community. There is very little work in measurement of enterprise integration. Measurement is often a precursor to science of a subject, so the lack of a measure impedes research work in enterprise integration.

In manufacturing, measurement has been used to quantify the properties of the manufacturing system. This is especially true of flexibility measures, of which there is an extensive record in the literature [30]. Less fully developed are manufacturing measures for other system properties such as agility, complexity, scalability, and reconfigurability. There is a need to develop measures of each of the integration types. Using these measures would enable companies to better design and better manage integrated systems

5 CONCLUSIONS

In this paper we define enterprise integration as encompassing five separate integration types of alignment, coordination, interoperability, data-sharing, and connectivity. Only with all five of these types present can an enterprise claim to be integrated. Using these definitions, many integration approaches were reviewed. Only ERP systems come close to attaining enterprise integration. The complexity of ERP is often the inhibiting factor in achieving all it promises.

It is our contention that there is no single integration technology or approach that is best in all business scenarios. Moreover, enterprise integration is an ongoing activity as reflected in the quote, “In contrast to machines, in which integrating of the parts into a cohesive whole is a one-time proposition, for social organizations the problem of integration is a constant struggle and a continuous process” [31]. To establish enterprise integration as an ongoing effort two issues of addressing the complexity inherent in integrated systems and measurement of integration need to be further researched.

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