Virtual Enterprises – Building Blocks for Dynamic e-Business

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Abstract

Dynamic e-business, as envisioned by several industry analysts and corporate leaders, involves the rapid teaming of companies with both familiar and new business partners in pursuit of specific market opportunities. For realizing this new generation business model, the ability to form, operate, and disband virtual enterprises will be the single-most important requirement. These short-lived, opportunity-based organizations leverage the individual capabilities of several member companies to form virtual enterprises that have resources equivalent to a traditional vertically integrated corporation. Before successfully applying this business model, however, several issues need to be resolved, such as building trust and a collaborative attitude amongst member companies, developing the e-commerce infrastructure for handling engineered-to-order products and services, building optimal coalitions for the job, etc.

This paper discusses our experiences in developing a web-based infrastructure for creating, operating, and eventually dissolving virtual enterprises. The primary operators of this infrastructure will be market makers offering custom products and services in various industries as well as corporations involved in bringing new products to the market.

Keywords: Virtual Enterprises, Dynamic e-Business, Next-Generation e-Markets, Collaborative Commerce, Vendor Coalitions, Virtual Corporation

1. Introduction

The last few years have seen rapid growth in business-to-business (B2B) e-commerce models – e-stores, e-procurement portals, and e-marketplaces to buy and sell various products and services from catalogs. Most industry analysts, however, believe that the simple transaction-based business model will have to be augmented with higher value-add services if these e-marketplaces are to remain competitive. Today, some e-marketplaces are transitioning into e-hubs that intend to support an end-to-end supply-chain spanning multiple enterprises for improving information and decision flow in order to optimize the performance of the extended enterprise. Production-oriented industries such as those involved in discrete and continuous manufacturing should benefit from this shift through better customer response, lower inventory costs, etc.

On the other hand, project-oriented industries such as construction, consulting, movie-making, defense contracts, etc. have a different set of business drivers as shown in Figure 1. Here coalition building, trust-enabling mechanisms, contract negotiation support, etc. are important. Interestingly, these issues are also important to corporations involved in introducing new products and services to the market (irrespective of their business nature) since the new product introduction business process usually has a project orientation.

It is in the above context that we envision a higher value-add service that will allow individual member companies to rapidly team up with both familiar and new companies to form virtual enterprises for pursuing new projects.

Operationally, the virtual enterprise could exist as a
formal team for the duration of the project or in some cases it could also register itself as a limited liability company (LLC). After completing the project, the virtual enterprise in most cases will disband and free up the member companies to pursue other opportunities. To further elaborate on the relevance of virtual enterprises in various industries, here are some examples:

**Construction.** In this industry, a general contractor normally puts together a team of specialists from various areas (plumbers, electricians, carpenters, masons, landscapers, etc.) to complete the construction project. The choice of the project members depends on several criteria, including skills, availability, geographic proximity, previous working relationship, etc.

**Defense Contracts.** In this industry, usually a prime-contractor puts together a team of companies (sub-contractors) to deliver the defense project. The prime-contractor takes the responsibility for delivering the project while managing the performance of the subcontractors. In many instances, there could be several layers of sub-contractors involved in the project.

**Movie-making.** In this industry, a team of specialists including cinematographers, lighting specialists, costume designers, director, scriptwriters, editors, etc., create the movie. After the movie is complete the team disbands to work on other projects.

**Consulting.** Most consulting projects require a team consisting of specialists in various fields. The project manager has to understand the customer requirements as well as create and manage a team of specialists. The team is formed based on the skills required, experience and availability of personnel, location preference, etc.

The creation of ad-hoc teams that form and disband per project is common in project-oriented industries. However, even within production-oriented industries one can envision rapid modification to a firm’s set of business partners in response to changing business conditions. Such rapid reorganization is not unthinkable, especially for non-core parts and services, which could be triggered by changes to the suppliers’ capacities, capabilities, part prices, etc. In some cases, short-term changes in the demand for the company’s products and services could be the reason for rapidly modifying its set of business partners. In any case, the mechanism to create and modify these relationships is akin to creating a new project team as discussed earlier for project-oriented industries.

The choice between using a coalition to deliver a customer project versus providing individual services directly to the customer should not be an issue. In terms of the organizational structure, the first case represents the customer simply out-sourcing the project to a system integrator or a general contractor while the second case represents the customer itself playing the role of the system integrator or general contractor.

Companies forming coalitions to pursue market opportunities is not a new concept and several coalitions are being formed every day. However, the manual and tedious process required for forming these coalitions limits the number of market opportunities that can be actively pursued. The current e-marketplace solutions do not address this situation and most focus on facilitating transactions related to standard parts and services. In the meantime, many market opportunities remain unfulfilled and many vendors still carry excess capacities that cannot be productively utilized. Reducing this inefficiency and reducing the cost of forming business relationships is the focus of our project on dynamic e-business based on virtual enterprises.

This paper is divided into 5 sections. Section 2 discusses in detail the lifecycle of a virtual enterprise. Section 3 explores the business issues involved in creating a virtual enterprise-based business. Section 4 presents a high-level view of the software components required to develop a framework for building e-markets that will support the creation of virtual enterprises. Concluding remarks including our experiences and areas for further exploration are covered in Section 5.

**2. Lifecycle of virtual enterprises**

The lifecycle of a virtual enterprise can be represented in terms of its various stages: formation, operation, and dissolution. Each stage has its own challenges and requires a distinct solution. The formation stage focuses on creating the right coalition of companies for pursuing a market opportunity. Once formed, the virtual enterprise requires an infrastructure to support its operations and collaboration amongst the member companies. Eventually, after the project is complete, the virtual enterprise is disbanded and its performance as well as the performance of the member companies is analyzed for use in designing future coalitions.

**2.1. Forming virtual enterprises**

The process of creating a virtual enterprise to pursue a specific market opportunity starts with a customer creating a Request for Proposal (RFP) or a Request for Quote (RFQ) for a product or service. The e-marketplace interprets the customer requirement using its domain expertise to identify the key capabilities required for delivering the solution. The list of required capabilities could have several items and each capability item could have multiple attributes. For example, a customer requirement for automated equipment for semi-conductor wafer slicing could generate a capability list that includes a robotic manipulator, vision system, motion table, wafer slicing tool, etc. In turn the robotic manipulator may have several attributes such as degrees of freedom, clean room
level, accuracy, repeatability, etc. The challenge here is to match these required capabilities against the vendor capabilities and locate vendors with the closest match along the multiple attributes. The matchmaking process culminates with the vendors having the closest match being invited to respond to the RFP/RFQ. Since many of the selected vendors may not have the entire set of required capabilities, they are also informed of those capabilities that they lack.

At this stage, the vendors themselves may use the e-marketplace by posing as customers to complete capabilities they lack by teaming with other vendors. This cascade effect allows creation of vendor coalitions at each level and the overall coalition has the required capabilities to satisfy the original customer requirement. If a market failure caused by lack of vendor capabilities is detected (i.e. no vendor coalition has the entire set of capabilities to satisfy the customer requirement) then the e-marketplace administrator gets involved in resolving the situation and any manually created solutions are stored for future use. This allows for a built-in learning mechanism that can improve the quality of solutions as more information is gathered over time.

The coalition thus formed can now be given an identity and other credentials that will allow it to operate successfully. As the above process suggests, successful coalition formation requires:

- adequately describing the market opportunity to alliance partners
- correctly identifying vendor capabilities required to fulfill the market opportunity
- adequately representing vendor capabilities in order to locate the right vendors for the job. In this area, the recently announced Universal Description, Discovery, and Integration (UDDI²) initiative from IBM, Ariba, and Microsoft is expected to play an important role.
- negotiating the transaction for cost, delivery schedule, quality, etc. with each vendor
- selecting vendors to work as a part of the project team taking into account the preferences of both customers and vendors
- establishing trust within the community so member companies are comfortable in both, competing as well as collaborating with each other
- supporting catalogs and market mechanisms for standard parts and services
- publishing the coalition structure and privileges of coalition members through LDAP directories

2.2. Operating virtual enterprises

The operation of virtual enterprises should be no different than the traditional operation of project teams. Controlled access to collaboration tools, document repositories, design applications, and project management tools (e.g. project scheduling, costing, etc.) are already available through several portals and application service providers (ASP). We envision providing appropriate credentials to the virtual enterprise participants so they can readily access these services based on pre-negotiated terms between the market maker and the ASP. These credentials could be in the form of digital certificates issued by the e-marketplace and supported by cross-certification between the e-marketplace and the ASP.

In addition to the ASP support, we think that the virtual enterprise should be supported by other business services such as legal, banking, insurance, etc. One can argue that these services could be represented as capabilities and the business service providers (BSP) represented as just another set of vendors in the e-marketplace. This model is definitely feasible. However, if the capabilities of some BSPs are either difficult to model or infrequently used then the interaction between the virtual enterprise and the BSP is best left to the coalition's project manager.

2.3. Dissolving virtual enterprises

This stage in the lifecycle of a virtual enterprise is important for learning purposes. Virtual enterprise participants (both customer and vendors) should be able to rate each other on various metrics related to timeliness, quality, costs, etc. Additionally, member companies within a vendor coalition should rate their experience with other business partners along metrics related to team behavior, quality, timeliness, use of information technology, etc. Such information should enable continuous learning within the process and also assist customers and vendors in making participation decisions during coalition creation.

In certain cases the virtual enterprise operation may take on a more permanent flavor instead of disbanding. The permanence could manifest in terms of longer duration of relationship, higher frequency of interaction, or change in the structure (such as incorporation or registration as Limited Liability Company). In this case the virtual enterprise could be treated as a traditional enterprise.

3. Virtual enterprises – concept to reality

Based on our early experience in working with market makers interested in e-marketplaces that support virtual enterprises, we found that the following issues require particular attention if this business model is to succeed:

- Industrial domain expertise is necessary to ensure that the e-marketplace can adequately satisfy the customer requirements. Additionally, the representation of vendor capabilities and related attributes is equally important in order to find suitable matches.
- Trust-building mechanisms should be employed so
participants can trust the quality of the results as well as feel comfortable while competing and collaborating.

- Team-building mechanisms should be employed to encourage cooperative behavior amongst member companies of the coalition

3.1. Trust through organizational relationships

Figure 2, which provides a high-level view of the virtual enterprise formation process, depicts several organizations associated with the creation and operation of virtual enterprises. Some of these organizations exist physically (sponsoring agency, market maker, and certified member companies) while others may exist only in cyber-space (virtual industrial parks). A description of the roles played by these organizations is as follows:

Sponsoring agency: Although not necessary for the functioning of the e-marketplace, sponsors such as economic development agencies within state governments and industry associations help in promoting the collaborative commerce concept amongst vendors and provide credibility to such e-marketplaces. In this sense the sponsoring agency improves the purchase confidence for the market participants. Additionally, the sponsoring agency could also assist in developing a pre-certification service for certifying companies within its jurisdiction.

Virtual industrial park: This organization is the cyber equivalent of the traditional industrial park and created under the auspices of the sponsoring agency. The fact that several e-markets exist today without any virtual industrial park may put in question the need for such parks. However, we think that this organization could help in establishing credibility of the e-marketplace and increase trust while dealing with new business partners. Think about whom would you prefer to deal with in new markets: a business affiliated with a well-known agency or a complete stranger. This issue will become more important as more e-markets develop to cater to global customers and suppliers. Here the presence of virtual industrial parks sponsored by government agencies should help in building trust.

E-Marketplace: This can be either an existing e-marketplace that wishes to offer a higher value-add service of virtual enterprise formation or a new e-market designed primarily to offer virtual enterprise formation service. From a trust-building perspective, the e-marketplace policies should be perceived as fair in allocating projects to member companies. Additionally, ability to support non-repudiation of transactions is equally important. The e-marketplace is also responsible for developing the domain expertise, either in-house or through relationships. Matching the customer requirements with an appropriate set of vendors is key to developing repeat business.

Registered member companies: The corporate registration process should ascertain the validity of applicant companies as well as their business capabilities before registering them as members. This is especially important for transactions involving engineered-to-order products and services since here the customers are purchasing vendor capabilities and not just standard products and services from catalogs. Some other trust building mechanisms include using industry standards, employing reputable agencies to evaluate member companies’ capabilities, etc.

Users within registered companies can be provided digital certificates for authentication, authorization, and digital signatures. Their participation and access privileges can be based on their roles within the member company.

Pre-certified companies. These companies have been identified by government agencies, industry associations, or other sources as possessing specific capabilities that could be useful in creating virtual enterprises. Inviting such companies to join the e-marketplace should help market makers in registering companies with appropriate skill set. Standardized representation of vendor capabilities as well as the use of standards such as UDDI should help immensely in this area.

In many instances not all the role players mentioned above will be present. However, the role that each of these organizations plays should help one to understand some of the underlying issues associated with building a dynamic e-business.

3.2. Domain expertise

In any business-to-business (B2B) e-marketplace, domain expertise plays a very important role. The process of virtual enterprise formation requires domain expertise at several levels. First, developing the specifications for
gathering customer requirements requires considerable
domain expertise. Second, in situations where the
customer requirements are stated differently than the
vendor capabilities, domain specific translation is required
to map the requirements to the capabilities. Third, when
the match between the required capabilities and the
available vendor capabilities is less than perfect, then
domain expertise helps in deciding which vendors to invite
for submitting proposals.

In the automation equipment manufacturing industry
for example, the customer requirement could be for semi-
conductor wafer-slicing equipment with a certain
throughput (the real requirements will of course be much
more complex). The expert has to provide the domain
knowledge to map these customer requirements to the
capabilities of the robot, clean room, material handling
equipment, vision system, etc. In case the matching
algorithms fail to find any perfect match for say, the
material handling equipment, then the domain expert may
suggest inviting specific vendors with a lower degree of
match (such as those selling material handling equipment
with more or less complexity). For efficiency, the mapping
should be done automatically and a human domain expert
engaged only when the pre-specified mappings fail. Capturing
the human experts solutions against failed mappings can help in resolving similar situations in future.

3.3. Team building and other issues

The success of the e-marketplace will depend on the
quality of coalitions that it creates. A key factor here is
how well these companies cooperate while competing
with each other. Carrot and stick policies such as profit
sharing, peer ratings, etc. should be devised to encourage
this behavior.

Supporting customer and vendor preferences during the
matchmaking process is also important to ensure that the
coalition has a desirable makeup. These preferences could
encompass several areas including preferred credit ratings
of member companies. For example, credit ratings related
preferences could be expressed as minimum credit ratings
required from the customer for a vendor’s participation in
the coalition or minimum credit ratings required from a
vendor in order to receive an invitation to participate, etc.
These credit ratings could easily be obtained from widely
known financial service providers such as Dun &
Bradstreet®.

Other issues involve security and access control to
information within the e-marketplace. These are frequently
raised issues by market participants and form some of the
key requirements. The ability to keep private customer
RFP information, vendor proposals, and interaction
between customer and vendors is also very important.

Some e-marketplaces may require that the identities of
customer and participating vendors be hidden during
negotiations to ensure fairness and equal opportunity. In
this case, the identities are revealed at the end of the
transaction when upon reviewing the proposals, the
customer selects one or more vendors for further
negotiations.

4. High-level solution architecture

The dynamic e-commerce framework presented here is
based on a layered architecture as shown in Figure 3. The
architecture is broad enough to support collaborative
business processes that span across multiple business
partners. Examples of such collaborative processes include
collaborative design, collaborative order fulfillment,
collaborative planning, etc. Hence the highest level shown
in the solution architecture here represents B2B
collaborative processes. Components supporting business
process flows and various decision support tools are
important for supporting collaborative processes.

However, for enabling dynamic, collaborative e-business
requiring rapid teaming amongst member companies,
virtual enterprises provide the key building block.

The solution architecture builds on several layers
including, the technology layer, the B2B integration layer,
the e-marketplace service layer, the e-commerce solution
layer, and finally the B2B collaboration layer. The
following sections discuss the functionality and
architectural details of these layers.

Most e-commerce solutions from software vendors
such as Ariba, CommerceOne, IBM, etc. address the
requirements from sections 4.1 through 4.4. The IBM, i2
Technologies, and Ariba alliance is addressing certain
items in Section 4.6.

4.1. Technology layer

The first layer in this architecture includes technology
components such as:

• Web application server for supporting web-based
  solutions
• Messaging server for supporting guaranteed message
delivery within or across enterprise boundaries
• Workflow server for supporting business processes
• LDAP directory server for sharing public information
  about users, member-companies, coalitions, and
  various system resources.
• Public Key Infrastructure (PKI) for issuing/revoking
digital certificates to/from users (certificate authority)
• User authentication and authorization server
• Applications for digital signature and encryption of
  important user information
• Synchronous as well as asynchronous collaboration
  mechanisms (discussion databases, etc.) for supporting
  bidders’ conferences, negotiations, and team work.
4.2. B2B integration layer

The components in this layer of the architecture represent a higher level of abstraction of the services available at the technology layer. The advantages provided by this layer are twofold: first it allows one to develop a customer solution by programming at a higher abstraction layer instead of programming directly at the technology layer. Second, components from various software vendors for workflow, security, collaboration, etc. can be plugged into the B2B integration layer. So any changes made to the components within the technology layer should be isolated from rest of the framework. The components in the B2B integration layer include:

- Trust and Access Manager for user authentication and authorization
- Business Flow Manager for managing the workflow associated with business processes as well as the activities associated with each step in the process graph
- Information Delivery Manager for interfacing with external applications and systems via Extensible Markup Language (XML) message sets and message adapters
• Solution Manager for managing the deployed solutions. The solution manager also provides generic facilities like logging, exception handling, events etc. that can be utilized by the rest of the components participating in a solution.
• Interaction Manager for rendering the end user desktop in accordance with their roles as well as managing the interaction with the end user
• Collaboration Manager for managing collaborative mechanisms such as discussion databases, etc.
• Signed Information Server for processing documents that are digitally signed and for supporting non-repudiation

4.3. E-Marketplace Services

This layer supports administration and content-related functions within any e-marketplace.

The major administration related functions include:
• Membership and registration services such as company registration, user registration, registration verification, user certificate issuance and revocation, etc.
• User profile management to support user preferences, subscription services, etc.
• Usage tracking of member companies, billing, etc.
• General exception management

The major content management related functions include:
• Catalog management for standard parts and services from multiple vendors
• Market information analysis and business intelligence based on tracking activity patterns and trends at both market level and member company level
• Personalization service for making the user interaction more meaningful

4.4. B2B E-Commerce Layer

This layer supports commerce and transaction-related functions in any e-marketplace.

The major commerce related functions include:
• Various auction models
• Negotiated settlement for both homogenous and bundled products and services
• Support for RFx and bids
• Trade exchanges for homogenous parts and services
• Fixed / contracted price sale

The major transaction related functions include:
• Order management for single and multi-item orders directed towards one or multiple vendors
• Customer invoicing for transactions involving multiple vendors
• Payment services such as purchase orders, escrow, etc.

4.5. Dynamic E-Business Layer

The dynamic e-business layer provides services such as:
• Business registration including capturing vendor capabilities. This description should preferably be based on industry standards such as UDDI.
• Automatic translation of customer requirements into capabilities required from vendors. Additionally, multi-attribute search for vendors who can provide desired capabilities against customer requirements with a certain degree of match
• RFx support for custom-built products and services that may require several levels of sub-contracting
• Multi-round negotiations between the customer and one or more vendors. In certain situations, the identity of the participants may have to be hidden to support anonymity
• Vendor coalition formation when a single vendor does not have all the required capabilities to support the customer requirements
• Support coalition operation by exchanging coalition information with service providers who provide collaborative tools to coalition members. Such pre-constructed information can help coalition members to readily access various collaborative services without delay and at pre-negotiated terms.


This highest layer in the architecture supports multi-enterprise business processes such as collaborative order fulfillment, collaborative product design, etc. In our view, these business processes can be implemented through customization of industry-specific process templates that contain models of:
• Process flows defined in an industry-standard process definition language
• Organizational structure in the form of various role players participating in the multi-enterprise processes
• Performance contracts in the form of trading partner agreements that model a common view of how business processes will be executed between business partners
• Appropriate decision support tools that can be integrated within the process flow and accessed through application adapters. The information exchange should be modeled using open standards and technologies such as XML.

Although collaborative business processes that span multiple business partners are being created today with custom solutions, the above framework has the advantage of being scaleable across increasing number of business
partners, being extensible to include new functions in the future, and being adaptable to handle changes in the business processes.

5. Concluding Remarks

The framework for supporting dynamic e-business as discussed in this paper is based on an ongoing research project on virtual enterprises. The project goal is to develop a configurable/customizable software framework to assist companies in rapidly teaming with each other to form virtual enterprises for pursuing specific market opportunities. This solution extends the current e-marketplace offerings that deal with standard products and services to support engineered-to-order products and services. Additionally, in case a single vendor does not have the capability to meet the customer requirements then a virtual enterprise with multiple vendors could be formed to deliver the custom solution. The potential to use such a business model exists in several industries such as construction, defense contracts, and consulting to name a few. Additionally, companies, irrespective of their industry, can use this model to rapidly introduce new products and services to the market by teaming up with new and familiar business partners.

The layered architecture presented in this paper leverages several off-the-shelf software components such as web application server, messaging server, workflow server, LDAP-based directory server, X.509 digital certificate servers, asynchronous collaboration mechanisms such as discussion databases, etc. The architecture also supports the ability to plug-in components from various vendors over time. By leveraging existing e-commerce solutions along with business process flow solutions and decision support tools, the architecture is designed to support various collaborative business processes. The virtual enterprise solution provides the building block to enable dynamic e-business by rapidly teaming member companies.

In our view, there are still several areas that need further study and exploration before virtual enterprises become part of the mainstream. These include:

- Developing ontology for virtual enterprises and coalitions that exist within or span multiple organizations. The ontology should cover several areas including organizational hierarchy, coalition member responsibility and accountability, centralized and decentralized trust networks, role-based access control schema for coalition members, etc.
- Models for representing customer requirements in both generic and industry/domain specific terms.
- Models for representing vendor capabilities and services in both generic and industry/domain specific terms, preferably using UDDI constructs.
- Models for representing terms and conditions within multi-party contracts. Additionally, mechanisms are required to automatically monitor and ensure contract compliance by the parties involved.
- Integration with collaborative environments to support virtual enterprise operations. The collaborative environments could be designed to be industry-specific and hosted through Application Service Providers (ASP).
- Models of partner interchange processes (PIP) for several industries similar to the RosettaNet PIPs for the electronic industry. This should also include support for industry-specific data exchange schemas for seamless flow of information across multi-enterprise coalitions.

As more companies feel comfortable with the notion of collaboration and as information technology reduces the overhead of communication across organizational boundaries, the potential for short-term, dynamic network of alliances to pursue market opportunities within a narrow time-window should grow stronger.

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