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Identifying Potential Suppliers for Formation of Virtual Manufacturing Systems

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Abstract

This paper describes a host enterprise search for suppliers for formation of a virtual manufacturing system (VMS). VMS means a host enterprise collaborates with a number of suppliers and distributors; the collaboration is dynamic due to changes in market conditions. Rather than using the traditional methods for supplier selection, this paper uses a search method that is based on world wide web (WWW) technology; the host enterprise searches WWW pages of suppliers for supplier selection. Formulation of host enterprise's selection criteria, dividing the selection process into different stages, and then employing a data collection system (based on XML and mobile agents) is described here.

1. INTRODUCTION

This paper is about a host enterprise searching for supply enterprises during the formation phase of a virtual manufacturing system (VMS). VMS means a host enterprise integrates a number of collaborating enterprises (supply and distribution enterprises), to manufacture a product satisfying the market conditions such as qualitative, agility, and leaness [1]. When market requirements are changed, a new class of products or an improved version of the product should be turned out to meet the new market requirements. In this case, the host enterprise may seek for a new combination of supply and distribution enterprises that are more suitable to manufacture the new class of products (see figure 1). This kind of *dynamic logic of organization and reorganization* makes VMS different from the other similar concepts like ‘enterprise integration’, and ‘extended enterprise'.

At the VM lab - Narvik Institute of Technology, we are building an autonomous data collection system to assist the three phases of VMS life cycle, namely, VMS formation - operation - and reconfiguration phases. This paper is specifically about the formation phase. During the formation phase of VMS, the host enterprise has to prepare its supplier selection criteria, and then it should employ some procedures for searching for collaborators. Though collaborating enterprises includes distributors too, this paper deals only with selection of suppliers. This is because we find it difficult to treat supplier selection and distributor selection under the same section. Suppliers selection and distributors selection are based on different criteria, therefore ought to be treated separately. In this paper, we present a methodology to formulate the host enterprise's supplier selection criteria. We present and analyze the important factors that should be taken into consideration when formulating the criteria list. We divide the formulation into different stages so as to enable the enterprise to evaluate a supplier at different strategic levels.

We also propose a data collection system to assist host enterprise's searching procedures. Traditionally, enterprises turn to outside sources such as professional contacts, trade journals, directories, and import brokers for supplier selection. In this paper, we propose a unique search method for supplier selection that is based on world wide web (WWW) technology, extensible markup language (XML), mobile agent and

Java technology. There are many advantages of using our proposed system over the traditional methods. The main advantages are (see also [2], [3], [4], [5]):

1. As Internet applications is easy to develop and inexpensive to run, many enterprises will embrace Internet to distribute their information. These enterprises may take information from their databases and render it as XML documents for easy sharing and consumption.
2. A large quantity of data that can be collected. Though we do not anticipate a mobile agent to collect large amounts of data from a supplier web, XML based system does allow a whole document to be transferred if needed.
3. Up-to-date data can be used at all the times. Mobile agents can be activated frequently to collect the newest data.
4. In addition to supporting the mobile agents for automatic retrieval of product data, XML based documents are (like HTML) human readable too. Therefore even if the mobile agents fail to function, XML documents pave way for human intervention (traditional methods).
5. Java based systems (mobile agents) offer platform neutrality, whereas XML offers data portability. By combining these two technologies, resulting system is suitable for inter-application data exchange that is vital for application sharing among multiple enterprises as in the case of VMS. A publicly available base DTD (document type definition) may serve as a vehicle for information interchange between enterprises (inter-enterprise), whereas additional DTDs within an enterprise enable separate intra-enterprise interpretation.

Organization of the paper is as follows: In the next section the different life cycle phases of VMS is presented. In the third section, we discuss about formulating the host enterprise's selection criteria. In the fourth section, we present the mobile agent based data collection system for the formation phase of VMS. Finally, in the fifth section of this paper, we present and analyze competing enabling technologies that are suitable for realizing the methodology we have proposed.

2. LIFE CYCLE PHASES OF VMS

The life cycle of the VMS will go through phases of *business opportunity identification*, *partner selection*, *VMS formation*, *VMS operation*, *and VMS*

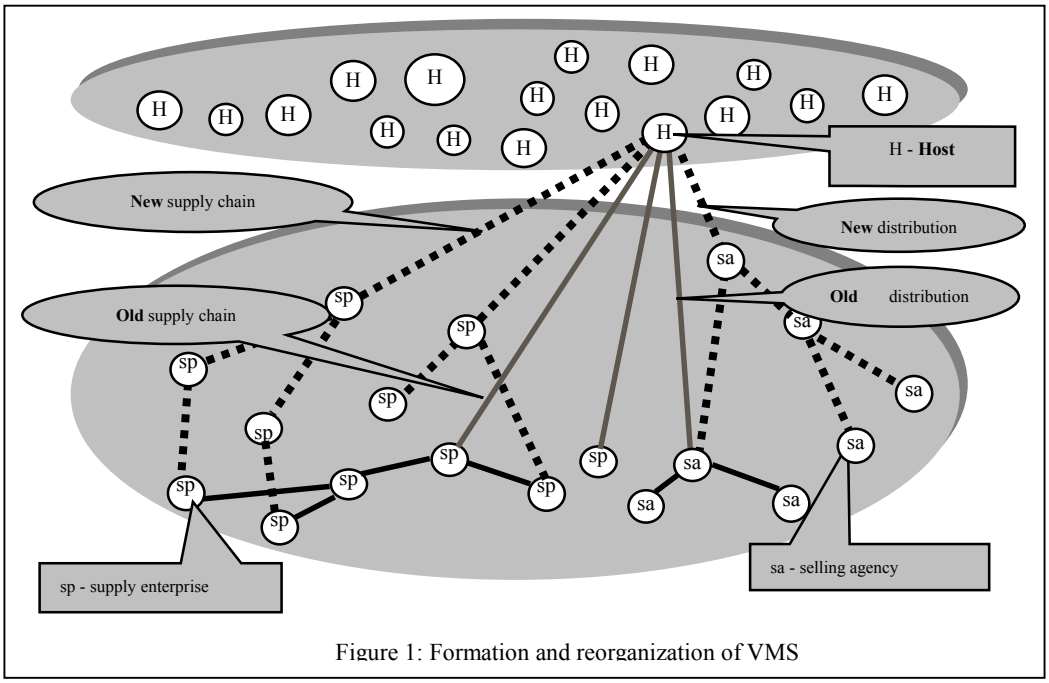

Figure 1: Formation and reorganization of VMS

reorganization [6]. This paper treats partner selection and VMS formation phases as one; the four phases are described below:

2.1 VMS formation phase

Before forming a VMS, profitability of a product (that is going to be produced) has to be assessed. This is done in the opportunity identification part of the VMS formation phase. Profitability of a product is assessed by extensive market analysis and research. After the opportunity identification part, the right collaborating enterprises must be found to manufacture the product; this is the collaborator (supplier and distributor) selection part of the VMS formation phase. Making the selection criteria for collaborator selection, searching for the collaborators, and forming a VMS is done in this collaborator selection part. The first thing done under this part is the preparation of the supplier selection criteria list. Then the host enterprise employs a data collection system to assist supplier selection. Because the data collection system is based on the use of mobile agents collecting data from suppliers' web pages, we divide the selection process into three stages (see figure 2):

1. *On-site selection stage*: Selection is done by the mobile agents themselves, on supplier workstation. After reading the supplier data, the mobile agent selects the supplier subject to the broad selection margins set for data like price, quantity, quality, delivery time, etc. On-site selection stage results in vague qualitative results like “good”, “acceptable”, “fair”, or “poor”.
2. *Quantitative performance evaluation stage*: After initial selection of a supplier by the mobile agent (on-site selection stage), the product data from the supplier is brought back to the host enterprise. A numeric performance measure is done in this stage by going through the supplier's data on overall production costs, quality assurance (or adopting to ISO standards), response-time (ability to meet random fluctuations in demand) and flexibility (capability to tailor product).
3. *Partnership assessment stage*: When a supplier passes the second stage of the selection process (quantitative performance evaluation stage), it has to go through the final selection stage before being accepted as a collaborating enterprise. In this stage, the numeric performance measure of the supplier is extended to include all other already accepted collaborators to see whether the supplier will perform satisfactorily under collaboration. Supplier's potentials for dependable partnership based on its infrastructure, economic strength, experience (or years in business), etc are considered in this stage.

Preparation of the selection criteria and division of the selection process into the three stages are explained in-detail in section three.

2.2 VMS operation phase

After forming a VMS, the collaboration is put to use for producing a class of products; this is the VMS operation phase. Like VMS formation phase, VMS operation phase too is based on mobile agents. However, unlike in the formation phase, mobile agents are launched only to the collaborating enterprises whose IP address (Internet Protocol address or number; mobile agents visit collaborating enterprises based on this address) are kept in the host enterprise's collaborators list. Also, due to the complexity of operations, in addition to the mobile agents, non-mobile (stationary) agents (divided into many functional units) are now needed. VMS operation phase is described in [7].

2.3 VMS reorganization phase

During the operation phase or after, the host enterprise may look for a new collaboration for producing the same class of product or a new class of product; this phase is called the reconfiguration phase. Clearly, formation and reconfiguration phases are similar. In this stage, the performance (quality) of a collaborating enterprise is compared with a new supplier for supplier

selection for the formation of a new VMS. Mathematical models are available for assessment of existing and new suppliers [8], [9].

3. SUPPLIER SELECTION CRITERIA

In this section first we present the factors that should be considered for supplier selection criteria, for the purpose of evaluating and selecting suppliers. Then we describe the methodology for dividing the selection process into three different stages, which was briefly described under section 2.1.

3.1 Supplier selection criteria

The basic factors for evaluating and selecting suppliers are 1) Agility 2) Quality, and 3) Leaness. We explain these factors below:

Agility: Agility is the capability of a supplier to react quickly and effectively to the continuos and unpredictable changes in the market conditions; for example, the capability of the supplier to satisfy a sudden increase in demand. In VMS environment, agility is an important character of a collaborating enterprise. “Poor” agility causes inventory costs (for early arrival of products), additional labor costs (late arrival), and poor customer responsiveness.

Quality: Before starting the inspection procedure to assure the quality of a product, the host enterprise may seek a registered ISO supplier, as that supplier is assured of a minimum level of quality constituting material standard. By using the standards, the host can compile a list of competing qualified suppliers, also receive an objective evaluation of suppliers through third party audits [10].

Leaness: The cost effectiveness of the supplier. After analyzing the supplier quotes, the host enterprise will prepare the final list of suppliers and evaluate the costs involved in each one. In addition to the supplier quotes, there are some costs that will incur; a complete list of costs can be found in [11]. Some of the costs are 1) Unit price. 2) Export taxes. 3) International transportation cost. 4) Insurance & tariff 5) Brokerage costs. 6) Letter of credit. 7) Costs of money. 8) Domestic and foreign freight cost. 9) Risk of obsolescence. 10) Cost of rejects. 11) Damage in transit. 12) Inventory handling charges. 13) Technical support. 14) Employees travel costs. 15) Survey & inspection costs. 16) Quotas. 17) Customs. 18) Container leasing. 19) Role of offset – under/over invoicing.

The remaining factors (other than the basic factors agility, quality and leaness) for evaluating and selecting suppliers are experience of the enterprise, financial strength, communication lines, inventory, and willingness to develop a long-term association with the host enterprise etc. [11].

3.2 Different stages of supplier selection process

It will be a massive task for the host enterprise to select a few suppliers from hundreds of potential suppliers. Therefore, we propose a systematic approach for this selection process. The selection process is divided into three stages see table 1.

On-site selection stage

The first stage is the on-site selection stage, where mobile agents are launched from the host's workstation to all the potential suppliers' workstations seeking supplier quotes and product data. The selection of a supplier is done on the supplier's work station based on broad margins for the basic selection criteria such as delivery time (agility), cost (leaness) and quality (ISO standard).

The visiting mobile agents are equipped with a simple logic controller. This logic controller will either select a supplier or reject it based on the inputs (cost, delivery time, and quality) to it. Cost can result in two values, 'high', and 'acceptable'; delivery time can result in three values: 'late', 'just-in-time', or 'early'; and quality results

in two values- 'satisfactory', or 'unsatisfactory'. The logic controller selects the supplier if all inputs are satisfactory (premise-1), or rejects it if one or more of the inputs are not satisfactory (premise-2).

Premise-1: ((cost is 'acceptable')⊥ (delivery is 'JIT'/'early') ⊥ (quality is 'satisfactory')) ⇒ (action is 'select').

Premise-2: ((cost is 'high') (delivery is 'late') (quality is 'unsatisfactory')) ⇔ (action is 'reject').

The output of logic controller is:
Controller = Premise_1 Premise_2

Quantitative performance evaluation stage
After initial selection of a supplier by the mobile agent (on-site selection stage), the product data from the supplier is brought back to the host enterprise. Among these competing suppliers, the best supplier for the host can be determined by the distribution of the expected performance scores from the numeric performance measures. Mathematical models are available for this purpose, for example [9], [12], and [13].

Partnership assessment stage
In this stage, the numeric performance measure of the supplier is extended to include all other already accepted collaborators to see whether the supplier will perform satisfactorily under collaboration. Supplier's potentials for dependable partnership based on its economic strength (financial strength, *'Keiretsu*'- or financial partners, inventory levels), infrastructure (communication lines, country regulations and standards, regional standards, exchange rate implications), and experience (years in business, leadership, goodwill) considered in this stage. As we have not seen any mathematical models for this stage, the top management of the host enterprise should make the evaluation at this stage.

4. DATA COLLECTION SYSTEM

In this section, we present a data collection system for formation of VMS. We assume that the information provided by the potential suppliers on their web sites are *structured-information* using XML conforming to a publicly available uniform *grammar*. Otherwise, in order to collect data from the sources that express information with different syntax and semantics, we have to use AI techniques or advanced mediators like Jedi [14].

4.1 A *specimen* product data markup language

Because of the fact that XML is extensible, a new set of rules (grammar) can be created, agreed upon, and standardized for product data encoding, say

Selection stage	*Purpose*	*Deciding factors*
1. On-site	To select a supplier after reading its product data and its supplier quotes. Selection is done on the supplier's workstation. This means, if this supplier is selected then the mobile agent will return to the host with the supplier data.	Broad margins for delivery time (agility), cost (leaness) and quality (ISO standard).
2. Quantitative performance evaluation	Selecting a supplier out of competing suppliers based on numeric performance measure. Mathematical models are used for this purpose.	Overall production costs, quality assurance (adopting ISO standards), response-time (ability to meet random fluctuations in demand) and flexibility (capability to tailor product).
3. Partnership assessment	The final evaluation done by the top management of the host enterprise. To determine how the supplier will perform in collaboration.	Economic strength, infrastructure experience, goodwill.

Table 1: Different stages of the supplier selection process

product-data markup language (PDML) together with a specification for it (DTD). However, defining a grammar is a challenging task, requiring specialized skills and comprehensive domain knowledge. A poor definition of grammar may lead to expensive inefficiencies into processing of data, and the enterprises may soon find that the grammar is insufficient for their work [5]. At present, there is no publicly agreed DTD for product data description. Until such an agreement is made, our proposed data collection system for formation phase of VMS will only be a conceptual one.

4.2 System architecture

Figure 2 shows the system architecture of the data collection procedure. The system starts by sending a search request to the search engine. The search request contains the key data about the product needed from the supplier. Upon reception of the search results from the search engine, the agent launcher of the host site, launches mobile agents to the supply enterprises identified in the search results.

The mobile agent travels to the supply enterprise and collects the product data encoded in XML format. With the XML parser (together with the DTD), this document is examined for key product data such as price, delivery time, and quality. Then the logic controller of the mobile agent determines whether to select this supplier by verifying that the values for the key product data are within the broad margins set for it. If so, the mobile agent takes the XML document with it when it returns to the host.

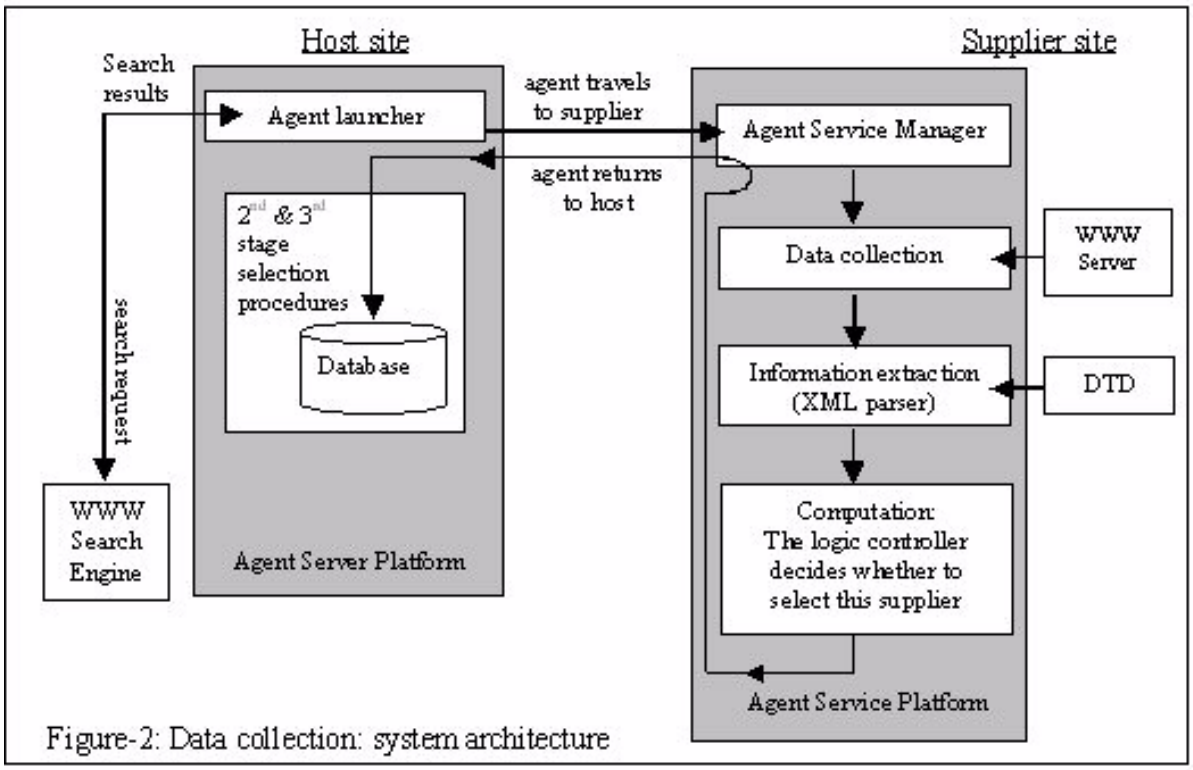

Figure-2: Data collection: system architecture

5. DISCUSSION

This paper is mainly about 1) The three stages of the supplier selection process, 2) The data collection system to support the first stage of the selection process, and 3) The enabling technologies to realize the data collection system. We present some remarks regarding these three points:

Though we have presented the first stage of the selection process (the 'on-site' selection stage) in-detail, we merely stated that there exist mathematical models to realize the second and third stages. Manufacturing Systems Theory developed by the Scandinavian school of systems theory could be used for creating mathematical models, and for optimization [15]. Manufacturing systems theory has been already used for such kind purposes. Also, Array-based logic (also developed at the Scandinavian school of systems theory) is an excellent tool to realize the logic controller mentioned in section 3.2 [15], [16].

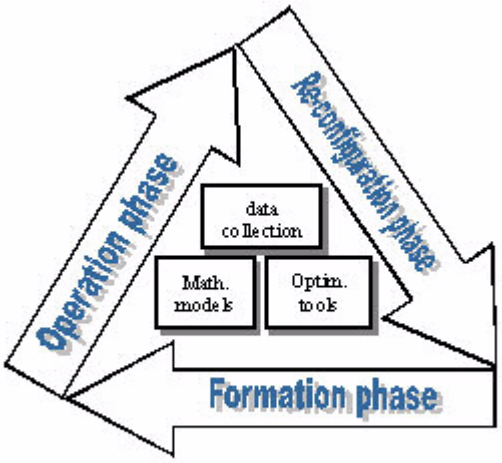

Figure 3: VMS: intergration of tools and methdos

The backbone of the data collection system is based on mobile agents launched by the host enterprise frequently visiting supplier enterprises. Rather than being a passive contributor, a supply enterprise may also inform the host enterprise about the availability of its newest data; whenever a supplier updates its product data on its web site, provisions can be made to inform the host automatically- either by sending an email or by launching a mobile agent from its server. By this mechanism, the host enterprise will always be aware of the suppliers' newest data. Another way of providing suppliers' new or updated data is to feed these data into the host enterprise's web site provided that the host on its web site hosts some "schema" or a form for fill-in.

We make use of three enabling technologies to realize the data collection system: 1) XML - the tool of choice for structured information in the networked manufacturing age, 2) mobile agents, and 3) Java - the only programming language that supports platform independency. By combining these three technologies, many advantages could be reaped in the field area of networked manufacturing, for example in VMS. Recently, there is a growing unification of XML and (object-oriented) database concepts. Because of this development, supplier data- whenever updated on its local database- could automatically generate XML documents for hosting on the web site. By this, updating local database (for intra-enterprise use) and updating the web site XML documents (for inter-enterprise use) becomes a singleton operation. This operation will be simplified with upcoming new Internet protocols based on XML, such as Microsoft's Channel Definition Format - CDF [5]. There is a shortcoming of XML that might otherwise improve the performance of data collection system based on it: handling of non-string data types. In XML (as opposed to CORBA), there is no native support for data types like integers, floating point numbers, boolean etc [3]. Only string types are supported, therefore values like price (floating point number), quantity (integer) has to be defined as a string then to be converted to the proper type by the application program (or agent). Though this is not a serious shortcoming (for VMS purposes), it does reduce the flexibility. One of the main concerns in using mobile agents is the agent server platform, which provides all kinds of services for the agents. There are

many agent server platforms (agent development systems such as Aglets [17], Bee-gent [18], Concordia [19], and Voyager [20]) to choose from, agents launched by the server platforms are not inter-operable. This means there is a restriction for errorless operation of VMS, that is - it is essential that all the workstations in the VMS deploy the same agent server platform.

The main idea behind theory and implementation of VMS is to build a fully automated system for all the phases of VMS (figure 3). A testing prototypical system for VMS operation phase was built [7], though building this prototype is much easier than for the formation phase, as only a limited (selected) enterprises participate in the operation phase. Building a testing prototype for formation phase is also easier as shown in this paper. But to put this prototype into practical use, it is a necessity for all the enterprises to use the same agent server platform (alternatively, a mechanism is found to make agents from different agent server platform communication - this is not viable now) and a common DTD.

6. CONCLUSION

Tools, methodology and the process of selecting supply enterprises for formation of a virtual manufacturing system (VMS) is presented in this paper. Rather than using the traditional methods for supplier selection, this paper uses a supplier selection method that is based on World Wide Web (WWW) technology, mobile agents and XML. The methodology presented here is highly efficient and effective (in terms of costs and time) provided that the suppliers encode their product data documents with publicly available DTD.

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