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A Knowledge-based Customization System for Supply Chain Integration

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ABSTRACT

Hostile environmental pressure on supply chain management increases emphasis on supply chain agility, integration, and visibility to respond rapidly, effectively and efficiently to changes in the marketplace. There is a need for new methods and tools to visualize the supply chain topologies which captures and recognizes the complexity of the supply chain network. This paper presents a Knowledge-based Customization System for Supply Chain Integration (KCSSI) which is developed based on three core technologies: visualization of topologies, network analysis, and knowledge-based system so as to obtain quantified actionable information and formulating strategies for supply chain configuration leading the long term success. The performance of the system is verified by a series of controlled simulation experiments conducted in a selected reference site. It is verified that the KCSSI improves supply chain visibility by recognizing the structure clustering and interconnection of the supply chain network, quantifying and exploiting holistic supply chain performance to provide measurable insights for the customization of the supply chain configuration leading to long term success.

1. Introduction

Under the hostile environment pressure on supply chain management such as globalization of markets, product proliferation, smaller ordering batch size with shortened product life cycle, lead to increasing emphasis on creating agile supply chain for supply chain flexibility. Agile supply chain aimed at responding and being actively adapted to a rapidly changing and continually fragmenting global market, by being dynamic, context-specific, aggressively changing, and growth oriented.

By having holistic scope of detailed information in real-time, supply chain visibility contributes in formulating an agile supply chain which allows the supply chain configuration to be reorganized effectively and efficiently, being aware of market change and monitoring supply chain performance, which significantly enhance competitive advantages. The holistic view on the supply chain configuration ,which is indispensable for supply chain management especially formulation of long term strategies.has been emphasized by various researchers (Perona & Miragliotta, 2004; Pitt, Merwe, Berthon, Salehi-Sangari, & Caruana, 2006; Wilding, 1998)

In the information age, automatic identification technologies, network infrastructures, and electronic data exchange technologies revamp the supply chain landscape, which bridges information gaps and allows an effective and efficient information sharing. With rapid adoption of the Radio Frequency (RFID) Technology and EPCglobal Networks, supply chain information floods into enterprise information system which enables holistic and sophisticated analysis of supply chain network.

Huge amounts of datasets create the opportunity for analyzing supply chain in the network approach. Similar to the email server data a several possibilities have been opened for detecting the social network in an organization (Barabási, 2002; Scott, 2000), and illustrating scientific collaboration networks structure from academic publication databases (Newman, 2001, 2004b; Wagner & Leydesdorff, 2005).

Applying network analysis is particularly relevant for supply chain management. Christopher (1992) recognizes supply chain as a network of organizations that produce values for the ultimate consumer, and supply chain is often represented as a network of nodes that interconnected by link representing direct interactions between nodes (Kerbache & Smith, 2004). Lazzarine, Chaddad, and Cook (2001) integrate supply chain analysis (SCA) and network analyses (NA) to introduce the ''Netchain'' concept. The concept interprets the supply chain in a network perspective on inter-organizational collaboration, with particular emphasis on the value creating and coordinating mechanism. Newman (2004a) modeled the supply chain as weighted networks – networks in which the links joining the nodes carry different weights, and modifies the standard techniques applied in networks problem to provide measurable insights such as robustness, efficiency, distance, centrality, etc.

The network topologies of the supplier chain network capture the pattern and behavior of the supply chain in a holistic view. Computer simulation becomes a powerful tool for realizing the emergence of the overall topologies and provides strategic insights. Pathak, Dilts,

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and Biswas (2004) studied the growth of supply network and provided valuable insights on how they were emerged into a wide range of topologies. Whereas Venkatasubramanian, Katare, Patkar, and Mu (2004) applied genetic algorithm (GA) simulation to observe the qualitative properties of various types of network topologies, in particular the efficiency, robustness, and path distance.

For achieving efficiency and effective management of supply chain, the customization of the supply chain is vital for tailoring the composition of value-added services provided by integrating various supply chain entities, according to demand specifications. It appears that there is little related research for process customization for supply chain management. Most of the previous research work for supply chain integration is information driven instead of knowledge driven. There is an emerging trend of the applications of knowledge-based system (KBS) in the customization of supply chain. Although some previous work has been found to facilitate the supply chain operation in various activities such as purchasing (Chan et al., 2006; Chou & Chang, 2007; Choy, Lee, & Lo, 2002, 2003), inventory management (Cheung, Wang, & Kwok, 2005; Li & Kuo, 2008), customer service management (Cheung, Lee, Wang, Chu, & To, 2003) Li and distribution (Chen, Huang, Chen, & Wu, 2005), relatively little research is found on applying the KBS for supporting supply chain strategic formulation.

In this paper, a Knowledge-based Customization System for Supply-chain Integration (KCSSI) is presented. The KCSSI attempts to integrate three core technologies: visualization of topologies, network analysis, and knowledge-based system to obtain quantified actionable information and formulate strategies for supply chain configuration leading to long term success. This allows the management and optimization of the supply chain in a macroscopic manner. In addition, the results of experimental verification of the performance of the KCSSI are also discussed.

2. Architecture of the Knowledge-based Customization System for Supply-chain Integration (KCSSI)

The KCSSI integrates the niche of network analysis and knowledge-based system for supply chain network management. The system featured with capability to visualize supply chain topology for capturing the entire supply chain activities in real time, and then the network in holistic perspective is analyzed to obtain quantified actionable information for strategic formulation. Finally, the knowledge-based system helps to formulate supply chain strategies which are capable of adapting and responding to the supply chain evolution, and helps to optimize supply chain configuration leading to the long term success.

Fig. 1 shows the system architecture of the KCSSI which consists of three major modules operating in an integrated and complementary manner. They are Visualization of Topologies Module, Network Analysis Module and Knowledge-based Customization Module, respectively. The theoretical basis of the system is supported by various data capturing and sharing technologies such as barcode technology, RFID technology and information exchange technologies for data acquisition and information sharing. Moreover, knowledge-based system is used to analyze the acquired information. Hence, supply chain configuration is formulated and customized for fulfilling operation specifications, acquiring knowledge from knowledge workers and also providing feedback to the supply chain network.

2.1. Topologies Visualization Module

Topologies Visualization Module allows real-time visualization of supply chain network. Fig. 2 shows the architecture of the Topologies Visualization Module. It describes how the module is connected to the product information network and how data are collected in particular in RFID means. The entire infrastructure is a distributed system with multiple independent resource suppliers and consumers communicating over the network to share product information. Enabled by a common information exchange interface and information provider discovery service, the data collector connects to the production information network in a transparent, open, and scalable manner.

The data transformation for topologies visualization involves four major steps, it is started by:

Step 1: The product trace is gathering in form of XML data and identified the weights of respective interaction,
Step 2: The trace is stripped into a list of records as an incidence list,
Step 3: Incidence lists are collected from the entire supply chain network and the incidence lists are aggregated into a two dimensional adjacency matrix, and
Step 4: The adjacency matrix is finally visualized into network diagrams which allow a holistic view of the visualization of the inter-linkages of nodes, structure and configuration of the supply chain network.

2.2. Network Analysis Module

Network analysis is performed by applying various mathematical methodologies and frameworks to obtain measurable insight about the performance of the supply chain network and the respective network participators. Unlike social network analysis which is an analytical tool using which a solid body of research has been developed; network analysis for supply chain network has received relatively little attention. Supported by the data captured from RFID and EPCnetwork, the present study illustrates the opportunities to apply network analysis in the supply chain context, and discusses the potential benefits that can be obtained.

2.2.1. Interpretation of network coefficients in supply chain context

Measuring coefficients (e.g. the centrality, sociometric index, etc.) help us to examine the role and influence of nodes within the network. For example, sociometric status reflects various activities of a node. The nodes attaining high sociometric status have an overall high inflow and outflow of physical goods. Such a node could be identified as a key party in the supply chain; or can be further interpreted as a logistics hub in the supply chain. Table 1 summarizes some general node-level coefficients and their respective implications on the supply chain network.

2.2.2. Defining the bottleneck

In the supply chain context, the bottleneck is defined as the supply chain party that has the minimal capacity for handling supply chain flows. Identification of the bottleneck considers the flow capacity. Although it cannot be reflected solely by referring to the structure and properties of network topologies without addressing the capacity issue, it is feasible to identify potential parties that have significant influence on prolonging the lead-time of the entire supply chain network.

Since the supply chain is an interconnected network, rather than considering the lead time of a particular connection or the lead time within particular parties, it is more appropriate to extend the scope of study to the total lead-time from the beginning of the product flow to the final destination in defining a coefficient for bottlenecks. In the present study, the latent lead-time is used to measure the influence of particular nodes on the lead-time on the whole network, which the latent lead-time for node i (L_i) can be expressed as:

$$L_i = \frac{\sum_{j=1}^{g} T_{ji}}{n_i} \quad (1)$$