Chapter XIX

Supporting Demand Supply Network Optimization with Petri Nets

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ABSTRACT

The present study implements a generic methodology for describing and analyzing demand supply networks (i.e. networks from a company’s suppliers through to its customers). There can be many possible demand supply networks with different logistics costs for a product. Therefore, we introduced a Petri Net-based formalism, and a reachability analysis-based algorithm that finds the optimum demand supply network for a user-specified product structure. The method has been implemented and is currently in production use inside all Nokia business groups. It is used in demand supply planning of both network elements and handsets. An example of the method’s application to a concrete Nokia product is included.

INTRODUCTION

Logistics refers to the flow of materials, information and money between the suppliers and customers. A demand supply network refers to the manner in which components flow from suppliers to the manufacturer’s plants, and finally to the end customers. The logistics costs associated with a demand supply network include such costs as freight, warehousing, interest rate, duties and taxes.

A typical problem that logistics professionals face in a global corporation is to find the cheapest and most reliable way of producing a product and delivering it to customers. Often the product structures and supplier bases vary considerably during a product design phase. The logistics manager must decide the most economical component suppliers and the best-positioned assembly factories over the product’s lifecycle. Typically there are hundreds or thousands of different demand supply network setup options for a given product. Therefore, manual analysis of demand supply networks is practically impossible.
Companies have considerable incentives to optimize their end-to-end demand supply chains. Firms approach this problem in two fronts: optimization of manufacturing functions on one hand and the demand supply chains on the other. As such, several methods for demand supply network analysis have been introduced in the literature. Most solutions use operations research paradigm—mixed integer programming—or discrete simulation to analyze demand supply networks (Simchi-Levi et al., 2003; Bramel & Simchi-Levi, 1997).

Recently, the industry has seen several examples of disasters brought up by broken demand supply networks (Norrmann & Jansson, 2004). A logistics manager must know all the demand supply network options available to reduce possible risks. This enumeration requires reachability analysis where each path (i.e. a possible demand supply network setup) is explored. Also, dynamic analysis of demand supply networks is required to explore whether a chosen network responds well to fluctuating customer demand. Mathematical optimization gives the optimal setup quickly via analytic or heuristic methods (Powers, 1989). However, optimization methods do not support the analysis of network dynamics. Discrete simulation, on the other hand, is excellent in dynamic analysis of a single demand supply network (Bowersox & Closs, 1989). Yet, it lacks the capability of choosing the best network structures, given by optimization. Thus, interplay of both techniques is required for a logistics professional to choose the best possible network (Riddalls, Bennett & Tipi, 2000). Simulation-optimization (Azadivar, 1999; Truong & Azadivar, 2003) has been developed to combine the advantages of optimization and simulation. However, the modelling languages used in optimization and simulation are very different from one another, and this creates a challenge for the co-use of the methods (Azadivar, 1999).

Petri Nets have been used successfully in modeling various kinds of systems, including telecommunication protocols and workflow systems (Jensen, 1996; van der Aalst, 1998). The hypothesis of this research was that reachability analysis is adaptable to solving small and medium size demand supply network optimization problems. As there are Petri net tools capable of dynamic simulation (van der Aalst, 1992; ExSpect, 1999), such addition would provide a single methodology amenable to both, static and dynamic analysis. Therefore, my research question became: “How to apply reachability analysis in demand supply network analysis?”

The result was a generic Petri Net model for describing arbitrary demand supply network options, and a reachability analysis algorithm that computes the network setups and costs from the Petri Net model. A Web-based analysis tool based on the methodology was constructed during 2004 and has been in production use since February 2005.

The rest of the chapter is organized as follows: the remainder of the introduction reviews the current approaches to demand supply network analysis. Section 2 gives the generic Petri Net model for demand supply networks through example and formal definitions. Section 3 presents the reachability analysis algorithm for the model. Section 4 presents a concrete Nokia case for the tool use. Section 5 concludes with discussion and future work.

**Literature Review**
