Optimal Supply Chain Services Management for SMEs through Integrated Model-driven Service System

Catherine Xiaocui Lou
Centre for Strategic Economic Studies
Victoria University
Melbourne, Australia
Xiaocui.lou@live.vu.edu.au

Wei Dai
School of Management and Information Systems
Victoria University
Melbourne, Australia
Wei.Dai@vu.edu.au

***Abstract*— Due to the lack of funding and expertise, small and medium enterprises (SMEs) have largely been excluded from benefiting the spill-over effect of web services-based supply chain systems. Theoretical and empirical researches are at a dearth in that the unmet needs of SMEs have not yet been promoted soundly. This paper assists in filling this gap by contributing to the literature through proposing an integrated model-driven service oriented supply chain framework that makes supply chain for SMEs affordable, easily accessible and free from technical 'hurdles'. The proposed services oriented supply chain system uses a novel framework with five core services coupled with a mathematical optimization model to achieve cost minimization, inventory optimization and reasonable lead time. Simulation results show that our proposed solution is better than the traditional supply chain systems without optimization. Furthermore, it is dynamic and flexible in normal business operation environments. Several simulation run-time examples are used to illustrate the proposed solution.**

Keywords - Optimal model-driven framework; Web Services-based Management Services; supply chain management.

I. INTRODUCTION

Small and Medium Enterprises (SMEs) comprise the largest business segment worldwide. For example, in Europe it is estimated that over 20.7 million SMEs make up 99.8% of all enterprises [1]. Similarly in Australia, they account for 99% of all businesses and are the engine room of the economy. According to the Australian Bureau of Statistics [2], these business entities comprise less than 200 employees and contribute to over 60% of the national employment, innovation, research and development (R&D) and industry value-added [3].

Globally, SMEs generate a huge share of the GDP and are a key resource for new jobs and ongoing employment. They are also a breeding ground for entrepreneurship and new business ideas. As of July 2006, nearly 140 million SMEs around the world employed 65% of the total work force. Apparently, SMEs have been contributed to boosting economic and social development worldwide [4]. Recently, with the advent of online trading, businesses have been able to reach new markets and shorten their supply chains to greatly improve their business connections.

Although there is significant SME participation contributing to the global economy, SMEs are relatively under-represented in the global economy, performing only between one quarter and one third of all manufactured exports, and accounting for less than 10% of Foreign Direct Investment (FDI) [5]. The main barriers that prevent SMEs from being globally active are related to: (1) high cost of hardware and software systems; (2) poor business infrastructure; and (3) inexperienced users of sophisticated software solutions.

As the theoretical and practical literatures of cost-effective and feasible supply chain solutions to SMEs are still sparse [6] [7], this research investigates a service oriented supply chain system. In this, services management operations are integrated with a formal approach in order to address some of the above issues concerning SMEs. The paper is structured as follows. The next section briefly reviewed the literature and our research goal. In Section 3, a supply chain services-based integration framework is proposed and an optimal model is developed for the system, furthermore, solution process associated is provided. Thereafter Section 4 figures out the proposed system architecture and gives out the random simulation example and related results. The last section concludes with the discussions of the limitations and the potential future directions.

II. LITERATURE REVIEW AND RESEARCH GOAL

In contrast to SMEs, the number and scope of successful applications of supply chain operation systems in large companies has grown significantly in recent years. As an illustration, Procter & Gamble drove out non value-adding supply chain costs to save the company over $200 million by using an optimization model with an interactive approach [8]. United Parcel Services (UPS) implemented an optimization modeling system that simultaneously determined aircraft routs, fleet assignments, and package route to ensure overnight delivery at minimal cost. Changes based on a modeling system saved UPS over $87 million between 2000 and 2002 [9].

To tackle the limitations of SME business engagements with its trading partners using the available e-business infrastructure and resources, Supply Chain Management (SCM) has been studied. SCM is about active management of supply chain activities and relationships to maximize

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customer value and achieve a sustainable competitive advantage [10]. It coordinates all the activities including the materials' physical transformation and information flow from suppliers to the end users. SCM represents a conscious effort by a firm or group of firms to develop and run supply chains in the most effective and efficient ways [11]. NAS defined an integrated supply chain as an association of customers and suppliers who work together to optimize their collective performance in the creation, distribution, and support of an end product (NAS 2000). Zaremba [12] stated that the supply chain aims to be able to link different functions and entities within and outside the company from raw materials to manufacturing, distribution, transportation, warehousing, and product sales. Along the supply chain, a potentially large number of trading partners such as manufacturers, parts suppliers, logistics suppliers, wholesalers and retailers work cooperatively [12]. Furthermore, Charleworth assumed that SMEs are not only seeking ways to integrate the disparate systems within the organization, they also intend to extend the whole domain beyond the boundaries of the organization to include their trading partners and customers [13].

E-business and supply chain applications often involve heterogeneous information resources that may take different standards, protocols and forms and operate in different environments with various complexities. Services-based system platform has advantages in meeting all these potential challenges. Momentum is gathering to apply services system solutions to supply chain problems and proves to be effective [14]. In 2008, Bose, Pal and Ye [15] introduced integration of ERP and SCM systems using the case of a valve manufacturer in China. The improved system successfully reduced lead time and up-grated inventory accuracy. Very recently, To achieve the environmental dynamics, Pan et al. [16] proposed Petri-net-based task model and achieved the connection of low level task with high level system services effectively through the task-to-service mapping algorithm. The research aims to establish a bridge between the arising tasks and potential services to achieve seamless tasks migrations among different application environments. Whilst considering the dynamic cooperation between services system and task framework from Pan et al. [16], our research focuses on the integration of services system and optimal modeling based on the Service Oriented Architecture (SOA). More recently, Choi and Wacker's paper [17] discussed the main theoretical research in the operation management and supply chain management at the aspect of theory building over a period of recent 10 years.

On the other side, in order to help resolve the systematic problems arising in the supply chain process substantially, many researchers are dedicated in the improvement and integration of mathematical models. Huang and Zhen [18] proposed the essential models of the processing in supply chain. In his research, by using the supply chain production strategies with symmetry information, the difference of production strategies under diverse information conditions was analyzed through simulation. However, the reality of producer and consumer determining the production strategies under the asymmetric information condition would cost more at storage and production processing stages. Moreover, for current global network system, not only the producers and stock-keepers relationship as addressed in this research but also the whole supply chain process partners need to be considered. Chang, Wang and Huang [19] studied the cost structure in supply chain. In his research, having the minimum Economic Order Quantity (EOQ) and minimum net profit requirements, the static cost optimization model for distributor was established, with the adjustable parts of customer order quantities as the control variables. Still, the research only discussed some parts of the supply chain operations. In the area of the responsive capacity planning and scheduling, Agrawal, Sephan, and Tsay [20] described a methodology for managing capacity, inventory, and shipments for an assortment of retail products produced by multiple vendors to maximize the retailer's expected gross profit with varied capabilities and demand uncertainty. By systematic examination of the models in SCM research, Narasimban [21] illustrates the five supply chain decision models that demonstrate the importance of integrating the decisions across the SC with their application in global SCM and potential areas. The global economic network also led to the researchers work on global or integrated supply chain models, such as *Huang* [22], Miller [23].

Though there have been well developed researches on the service management and operations optimizations respectively to support SCM, there is few system that successfully combined service management with optimal modeling seamlessly to achieve the real-time integration. To fill this gap, this article illustrates a model-driven based integrated supply chain service framework so that the participants can implement their roles and engagements for efficiency and profitability

III. Solution Approach

A. *The Proposed Model-driven Integrated Supply Chain Services-based Framework*

The main reason behind the SOA adoption is its support for flexible resources allocation, selection and management for SMEs. The model driven approach is to enable a dynamic solution model to match the nature of the tasks. This is to be incorporated into the proposed SOA architecture. The alternatives would be a grid or cloud-based model where the proposed solution model for SMEs would be generated.

Our proposed system incorporates the optimal mathematical modeling into the practical supply chain services management framework through combining both theoretical foundations and business functions within a web services-based system. Further to the research work of Dai and Uden [24], the integrated supply chain service system designed in this paper aims to address the entry barriers of SMEs through the development and provision of core system services that are dynamically integrated with business services to facilitate business operations among trading partners (i.e., consumers and suppliers) in the supply chain. This will require a novel infrastructure in the aspect of integrating formal modeling with supply chain management processes among trading partners for SMEs. To ensure the

effectively using of available trading network resources and delivering practical benefits to SME users, our system help SMEs interacting with each other more easily and economically. This is achieved through the integration of global market resources and the real-time communication and interaction support by the proposed service system.
The proposed services oriented supply chain integration has a specialized centre service that coordinates all the businesses including consumer and provider participants within its landscape. The system integrates all the resources within a defined landscape to achieve the goal of optimizing the whole supply chain management through five core services in SOA. These five core services are in the following categories: Knowledge Management Services, Data Management Services, Task Management Services, Information Services and Communication Management Services [24]. With the help of the core services, the higher-level services such as Goal Directed Inference (GDI) service and Event Driven Inference (EDI) service are developed. GDI and EDI services respond to SME users' needs in different ways, e.g. event-driven by triggering purchase order issuing when sales or inventory reaches to a certain level, and goal driven by focusing on user specific request such as fulfilling a specific purchasing request. GDI is particularly supported by two services that are plan generation and plan execution that is supported by the mathematical programming in the next section. GDI provides a model-driven solution in the proposed system. Figure 1 t as attached to this paper shows the technical configuration of the services system.

The participants are supposed to be SME users, who can access the market information in relation to their objectives including low cost and timely delivery through highly optimized and dynamically integrated supply chain channels. The requirements on SME users are to make their consumers requirements for certain product and service in standardized format. The system is to ensure the requirements are transparent to services providers. The process of running the supply chain is executed by the Knowledge Manager (as shown in the Figure 1), which will be improved by the optimization model mentioned in the next section.

B. *Optimal Model-driven Development in the System*

One important contribution towards services oriented supply chain system is to incorporate an optimization model into the service system that includes GDI service. . In order to achieve maximum benefits among the SMEs within the objective supply chain system, a nonlinear optimization model is introduced and described as below.

The annotations for the model are listed as follows.

Sets:

Q : Quantity of the primitive order

Functions or variables in the objective function:

$F(Q)$: Functions for the final integrated supply chains profit;

$f_i(profit)$: Each sub- supply chain profit;

$f_R(price)$: The total income;

$f_P(\cos t)$: The material cost;

$f_c(inventory)$: The inventory expense;

$f_t(transport)$: The transportation fare;

Parameters:

t : The time the whole proposed supply chain process in our system will take;

$T_{\lim}$: Requirement of the time spending;

q_{ij} : Presents the quantity of each independent supply chain.

Optimal Model:

$$F(Q) = Max \sum_{i=1}^{n} \{ f_i(profit) = f_R(price) - f_P(\cos t) - f_c(inventory) - f_t(transport) \}$$

$$subject\ to\quad f_i(profit) \geq \bar{R} \Leftrightarrow Min \frac{1}{2} \alpha \{ f_R(P) - [f_P(C) + f_c(I) + f_t(T)] - \bar{R} \}^2 \quad ....(1)$$

$$Min\{ f_P(C), f_c(I), f_t(T) \} \quad ....(2)$$

$$t \leq T_{\lim} \quad ....(3)$$

$$\sum_{i=1}^{n} \sum_{j=1}^{m} q_{ij} = Q \quad ....(4)$$

$$q_{ij} \geq 0 \quad ....(5)$$

where Objective function defines the maximum function which including the objective function for the system profits. The part of constraint (1) $Min \frac{1}{2} \alpha \{ f_R(P) - [f_P(C) + f_c(I) + f_t(T)] - \bar{R} \}^2$ is the quadratic penalty function to limit the expectation minimum profit. α is the penalty factor, $\bar{R}$ is set to be company's minimal profit requirement. The second constraint $Min\{ f_P(C), f_c(I), f_t(T) \}$ minimizes the fee of all expenditure therefore to control the cost of the whole supply chain process. The third constraint $t \leq T_{\lim}$ is set to meet time requirement from order. Last, q_{ij} presents the quantity of each independent supply chain. The objective is to maximize profit, or reciprocally minimize cost.

To simplify the understanding and usage of the optimal model, we supposed the incoming order with certain price of the productions including unit cost for the inventory, and transportation fare. However, it could certainly be extended to sub-functions for each supply chain processes. For example, the material cost function $f_P(\cos t)$ could be calculated depending on the different proportions of ingredients.

Comparing to the previous supply chain models being used practically, we introduce a penalty function into our optimal system to keep track of the control of the system profit. We also set time constraint to ensure the implement procedure complying with certain required delay time.

C. *Solution Process*

The algorithm of our proposed optimized supply chain is depicted in Figure 2.

Once order requirement comes in, it will trigger the real-time response procedure of our service oriented supply chain system. The basic rules for the system considering the optimal model are, ‘first come first serve’, ‘simultaneous processing of multi-services under time and capacity constraints’, and ‘check the stock inventory before manufacturing’. Figure 2 describes the main process of the plan generator processing the orders under optimal rules. This algorithm follows up the optimal model described earlier in Section III B.

When the primitive order task entered into the system shown as ‘Demand’, the procedure is activated. The system will check the inventory based on the ‘check the stock inventory before manufacturing’ rule. The system then calculates the cost involved and generating production order under the constraints of the model discussed in Section III B.

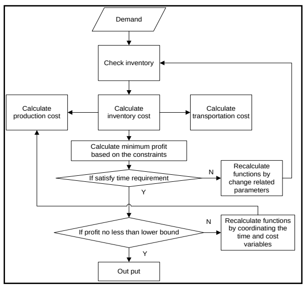


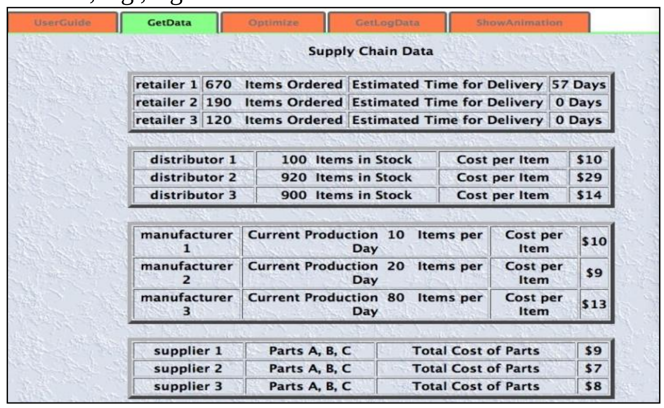
Figure 2 Optimized Model-driven Supply Chain System

IV. SIMULATION AND APPLICATION

The optimization process adopts a multiple objectives, multiple agents approach [25]. The global optimal solution is obtained by mathematical programming. Scenario analysis approach is adopted to illustrate how the proposed system works and compare the performance of the proposed system with the other alternatives.

The processes of one scenario as an example which is simulated by our model-driven based supply chain services system are listed as below. This system is currently under experiment with twelve business entities across four sectors, i.e., retail, distribution, manufacturing and material supply. For run-time simulation, retailers issued purchase orders that trigger dynamic supply chain channels formation. The initial status of simulation in our system is conducted by randomly generated purchase orders from retailers, , e.g., retailer 1 ordered 670 items in figure 3. Secondly, these figures are screen shots that were dynamically taken during the running of our experimental system. Since the initial situation for order is produced randomly by the system, the scenarios could be different when every time you run the experimental system. Last, to help understand our example, it needs to emphasize that our system is working on integrating all the participants’ resources of the supply chain and endeavoring to optimize the allocations and chains arrangement. Therefore, the optimization process of our system is trying to work out optimal supply chain solutions for all the participants to save time and cost.

Briefly introducing, the processes for the simulation are divided into: set up the model (including the request, available resources, manufacturing and inventory capability, etc.), e.g., figure 3; calculate the scenario with traditional approach which is not using combination of services management and optimal model-driven, e.g., figure 4; give out our proposed optimal supply chain services management solution, e.g., figure 5.



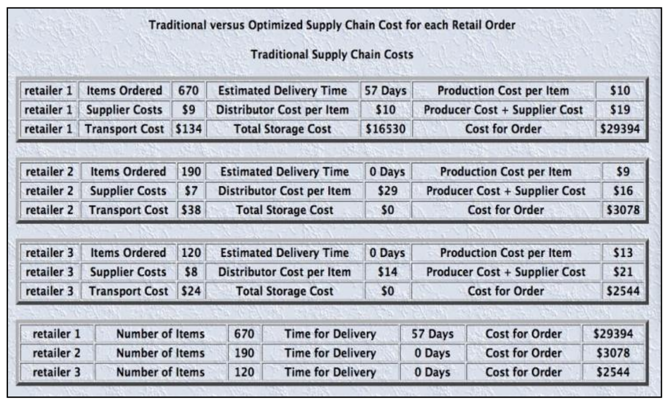
retailer 1	670	Items Ordered	Estimated Time for Delivery	57 Days	
retailer 2	190	Items Ordered	Estimated Time for Delivery	0 Days	
retailer 3	120	Items Ordered	Estimated Time for Delivery	0 Days	

distributor 1	100 Items in Stock	Cost per Item	$10
distributor 2	920 Items in Stock	Cost per Item	$29
distributor 3	900 Items in Stock	Cost per Item	$14

manufacturer 1	Current Production 10 Items per Day	Cost per Item	$10
manufacturer 2	Current Production 20 Items per Day	Cost per Item	$9
manufacturer 3	Current Production 80 Items per Day	Cost per Item	$13

supplier 1	Parts A, B, C	Total Cost of Parts	$9
supplier 2	Parts A, B, C	Total Cost of Parts	$7
supplier 3	Parts A, B, C	Total Cost of Parts	$8

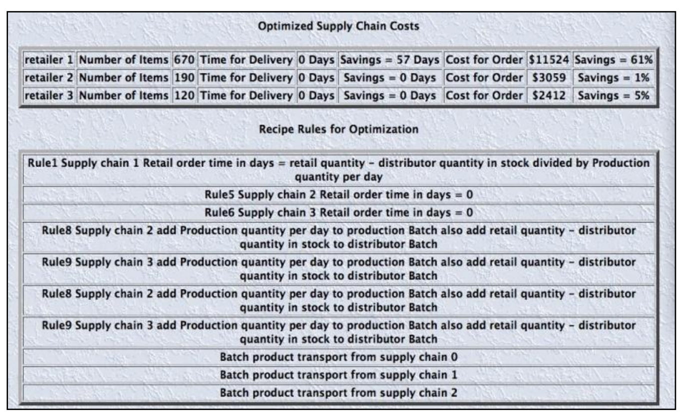
Figure 3 Setting Up the Model



retailer 1	Items Ordered	670	Estimated Delivery Time	57 Days	Production Cost per Item	$10
retailer 1	Supplier Costs	$9	Distributor Cost per Item	$10	Producer Cost + Supplier Cost	$19
retailer 1	Transport Cost	$134	Total Storage Cost	$16530	Cost for Order	$29394
retailer 2	Items Ordered	190	Estimated Delivery Time	0 Days	Production Cost per Item	$9
retailer 2	Supplier Costs	$7	Distributor Cost per Item	$29	Producer Cost + Supplier Cost	$16
retailer 2	Transport Cost	$38	Total Storage Cost	$0	Cost for Order	$3078
retailer 3	Items Ordered	120	Estimated Delivery Time	0 Days	Production Cost per Item	$13
retailer 3	Supplier Costs	$8	Distributor Cost per Item	$14	Producer Cost + Supplier Cost	$21
retailer 3	Transport Cost	$24	Total Storage Cost	$0	Cost for Order	$2544

retailer 1	Number of Items	670	Time for Delivery	57 Days	Cost for Order	$29394
retailer 2	Number of Items	190	Time for Delivery	0 Days	Cost for Order	$3078
retailer 3	Number of Items	120	Time for Delivery	0 Days	Cost for Order	$2544

Figure 4 Traditional Approach to this Scenario



retailer 1	Number of Items	670	Time for Delivery	0 Days	Savings = 57 Days	Cost for Order	$11524	Savings = 61%
retailer 2	Number of Items	190	Time for Delivery	0 Days	Savings = 0 Days	Cost for Order	$3059	Savings = 1%
retailer 3	Number of Items	120	Time for Delivery	0 Days	Savings = 0 Days	Cost for Order	$2412	Savings = 5%

Recipe Rules for Optimization

Rule1 Supply chain 1 Retail order time in days = retail quantity – distributor quantity in stock divided by Production quantity per day
Rule5 Supply chain 2 Retail order time in days = 0
Rule6 Supply chain 3 Retail order time in days = 0
Rule8 Supply chain 2 add Production quantity per day to production Batch also add retail quantity – distributor quantity in stock to distributor Batch
Rule9 Supply chain 3 add Production quantity per day to production Batch also add retail quantity – distributor quantity in stock to distributor Batch
Rule8 Supply chain 2 add Production quantity per day to production Batch also add retail quantity – distributor quantity in stock to distributor Batch
Rule9 Supply chain 3 add Production quantity per day to production Batch also add retail quantity – distributor quantity in stock to distributor Batch
Batch product transport from supply chain 0
Batch product transport from supply chain 1
Batch product transport from supply chain 2

Figure 5 Proposed optimal supply chain services management solution

The result shows that for the scenario absent of supply chain integration, the three different supply chains’ total cost adds up to $35016 and the lead time is 57 days. While through using our proposed model in this paper, the total cost is reduced to $16995, which saves more than 50% overall.

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Though the savings in the costs are disproportionately distributed, it is apparently that all the SMEs are better off. The lead-time reduced to 0, which is consistent with the “just-in-time” approach.

SME users can conveniently access our new integrated model-driven service through a Web browser or hand-held devices such as mobile phones from any corner of the world. An operational system configuration can be found in Figure 6.

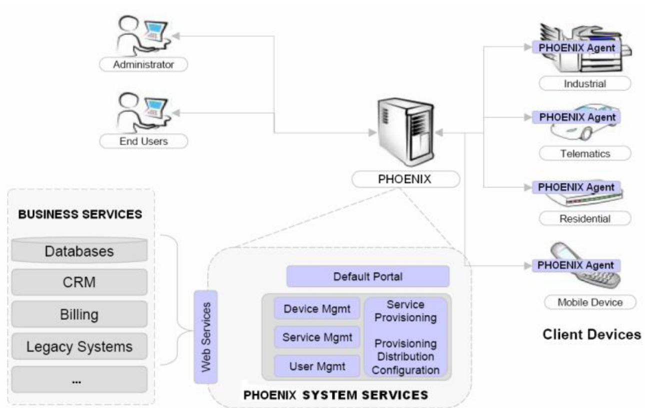

Figure 6 The PHOENIX Services System Architecture

V. CONCLUSIONS AND FUTURE WORK

The research proposed a feasible and cost-effective way to enable SMEs to access supply chain management tools, which used to be the privilege of large corporations. The marriage between supply chain integration and mathematical optimization techniques is a critical contribution to innovation by this research. The simulation results show that our proposed framework significantly improves SMEs' situation by saving costs and reducing the lead time.

This paper is subjected to the following limitations: (1) the simulation is not robust enough to produce any general conclusions; (2) minutes of all the details within the supply chain has yet to be specified; (3) the input and output communication among all the parties have not been considered.

Future research will focus on applying the proposed framework to the real world situations. In addition, a mobile set- based model can also be designed to free users from all the details of supply chain and arduous supply chain management activities.

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ATTACHMENT

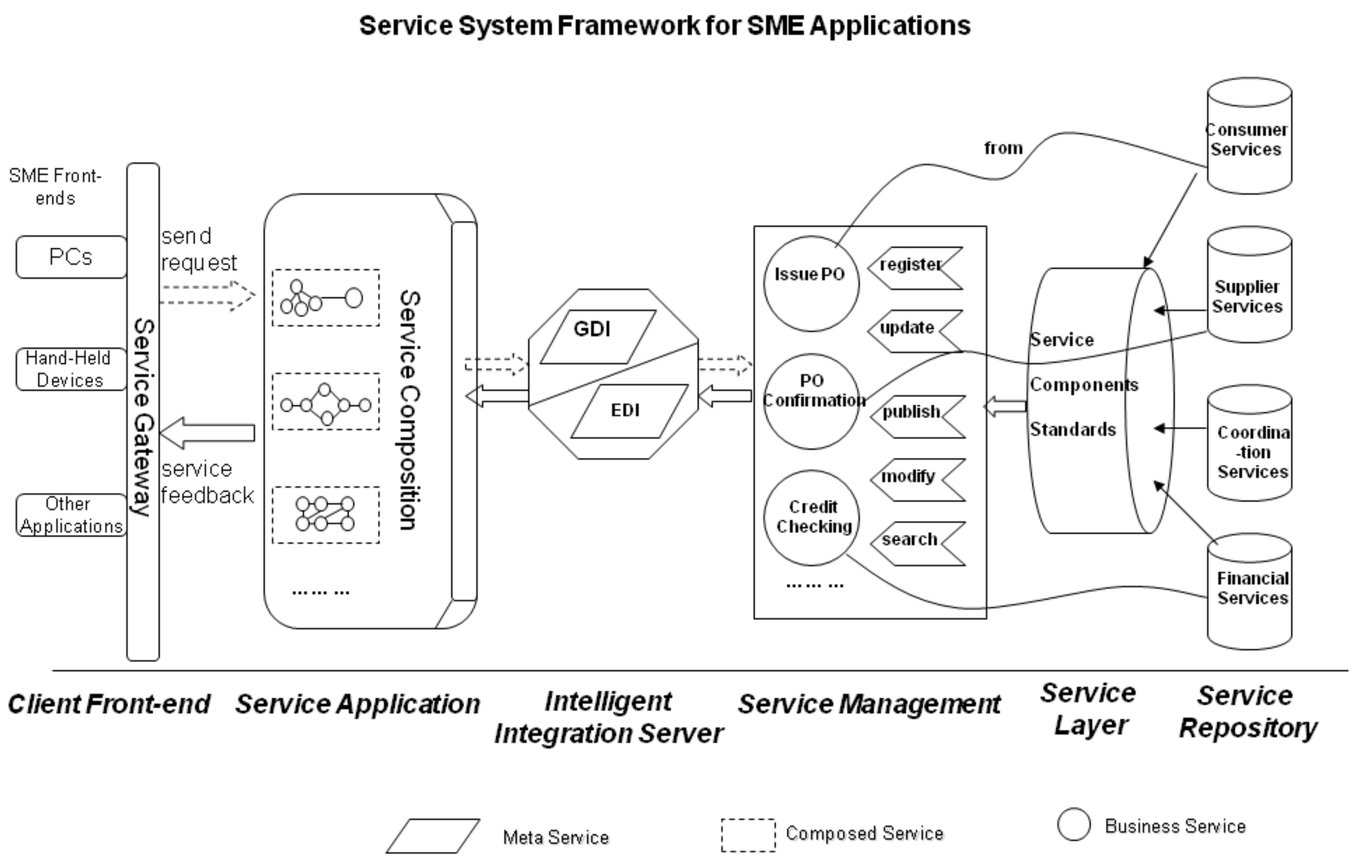

Figure 1 Services Oriented System Architecture