SOA-based framework for supply chain selection in network of production competences

Sinopsys

Service Oriented Architecture (SOA) is cutting-edge software technology for enterprise application integration and business processes implementation. This paper presents a research of opportunities and feasible practices for using its concepts in implementation of network of production competences, with specific objective to enable semi-automated selection of supply chain for incoming inquiry and quotation generation.

Introduction

Today, mass-customisation increases demand for wider scope of product specifications, quality levels and delivery times. Diversification of customer orders, as well as fast-moving markets, increases the pressure on long-term planning activities and introduce significant uncertainity in determination of quantity and frequency of sales. Required level of flexibility, needed to deliver the customer response, grows rapidly.

One of the internal measures for management of mass-customisation phenomena demands is product modularisation. It is performed with two specific objectives: to enable customizable product options and reduce manufacturing complexity.

Atomisation of the manufacturing process is the crucial driver for widening a range of options in managing customisation levels, costs and lead time. It is enabler for alignment of the product lifecycle with supply chain, characterised by the most effective balance of specialisation level, productivity, cost and manufacturing scale of internal and external resources.

Current view of supply chains is shifting from linear chains of supplier's supplier to customer's customer into complex networks which entail groups of companies with varying degrees of integration. Networking in supply chain management follows the concept of extended enterprise [1]. Extended enterprise is defined as a function of closer coordination in the design, development, costing, and the coordination of the respective manufacturing schedules of cooperating independent manufacturing enterprises and related suppliers [2].

Key preconditions for networking are advanced information technology (IT), specialisation, and outsourcing [3]. They must be implemented with primary objective to support resolution of major obstacles for succesfull supply chain collaborations, defined [4] as:

- Underestimating the scale of change and turbulence that partnering involves
- Priority conflicts left unresolved
- Over-reliance on good interpersonal relations
- Cost, benefit, and value adding models not defined
- Insufficient focus on the long term

ICT leads to quicker response to other elements in a supply chain and provides a virtual cooperative platform for coordination among relevant elements within the chain [5]. It is main enabler for a virtual enterprise - a network of independent organisations that jointly form an entity committed to provide a product or service [2].

This paper presents a research of opportunities for implementation of new approach in ICT support of supply chain management. It is motivated by advances in development of Service Oriented Architecture (SOA) - cutting-edge software technology for enterprise application integration and business processes implementation. This approach overrides the traditional concept of static sequential or hierarchical supply chains and introduces integrated, flexible and dynamic collaboration environment – an open, service-based, broad-range, virtual, self-managed network of production competences [6] and supply chain paths as its market appearances. The concept provides environment in which excellence of individual partners is virtually detached from their legal background to assemble an space of equal opportunities for managed participation in multiple supply chains.

Network of production competences

General objective of a network of competences is to improve responsiveness and competitiveness of a local industry by implementing an integrated supply chain management. It is defined as concentration of actors within manufacturing sector, where the common denominator is that they draw from the same resources and/or competences in order to improve their ability to perform on a market [7]. Potential impact of a partner to improvement of general ability to perform is measured by partner competence. Competence is defined as quantitatively described ability of a partner to perform in certain area of business.

Quantitative description of a competence is necessary for IT support in selection of the optimal chain of competences for responding to external inquiry. Primary tool for this is selection engine – a software for generation of optimal supply chain path for production and delivery of product with specification from customer inquiry.

Basically, competence describes the quality or quantity of stock and manufacturing resources, knowledge and experience. However, broad-range feature of a network introduces all other skills and resources which can add value to a product, process or network, in general - negotiation strength, legal experience, ability to generate additional sales leads or recognize cross-sale and up-sale opportunities, client relations, government relations, etc. All these skills and resources could improve the position of a recognized supply chain path on market, but more important – they could contribute to prolongation of its life, or preservation of its continuity by reusing it in other business ocasions.

Figure 1 shows an example of one supply chain path, generated by network of compentences.

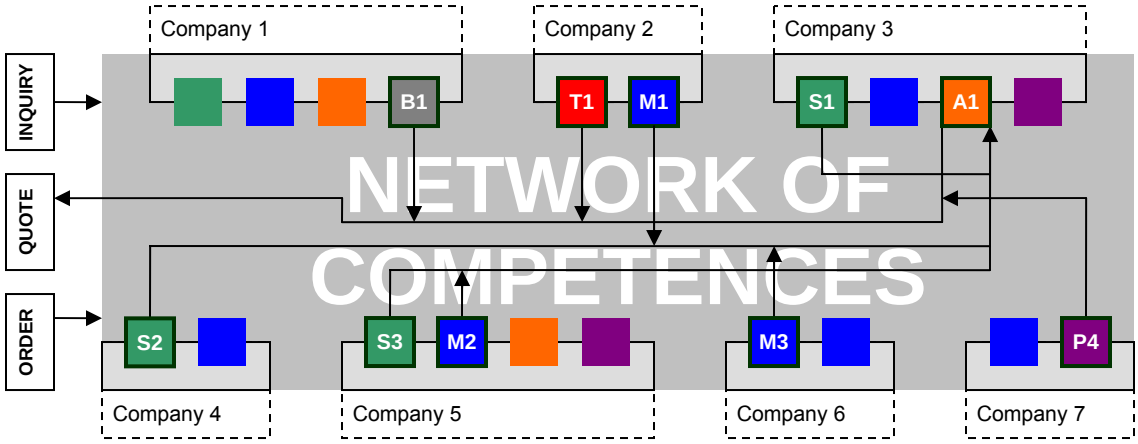

Figure 1. Example supply chain path, generated within network of competences

Specified product's BOM contains three parts which can be assembled at A1 assembly line of company 3. One of the parts match the exact requirements and is available to promise, at the time of assembly operation, at stock S1 (company 3). Two other parts has to be manufactured from raw material available to promise in stock S2 and S3. Selection engine recognize M2 machining competency as the most efficient in manufacturing of part 3, as well as M1 and M3, respectively, for the manufacturing of part 2. P4 packaging competency is selected from company 7, and T1 transport competency from company 2. Finally, company 1's business competence is selected for market research, price negotiation, contract development and risk management.

Criteria for supply chain path is selected and prioritised by a customer, as imperative or loose constraints. Namely, selection engine is capable for generation of multiple variants of supply chain path, depending on given priorities (price range, deadline, non-functional quality features, etc.). All matching variants are presented to a customer as an inquiry response.

Integrated part of a path selection is identification and calculation of risks which might threaten the process of order fullfillment, for each of selected path variants. Also, path selection must include analysis which would result with risk management guidelines and proposed specific measures, targeted on execution of pre-defined compensation and fault handling scenarios.

Web-based infrastructure for inquiry processing and integrated order management

By default, network of production competences is open. Openness of the network could contribute significantly to flexibility and diversification of the individual company by offering the opportunities for exploiting unknown vendor resources or establishment of feasible relations, which were previously not possible, due to high co-ordination costs or transaction risks. With regard to this, it is obvious that main technology enabler for seamless communication and collaboration within network is internet, specifically – world wide web.

Therefore, a web-based network collaboration environment, shown at Figure 2, has been designed. It is the backbone for supply chain path selection and integrated order management, consisting of following components:

- Public web portal;

- Extranet;
- Supply chain path selection engine;
- Integrated order management engine;
- Network information pool; and
- Knowledge repository.

Primary technology, used for implementation of described web-based collaboration environment is Service-Oriented Architecture (SOA) [8], and web services technology stack as its basis. Technical implementation issues will be described later in this paper.

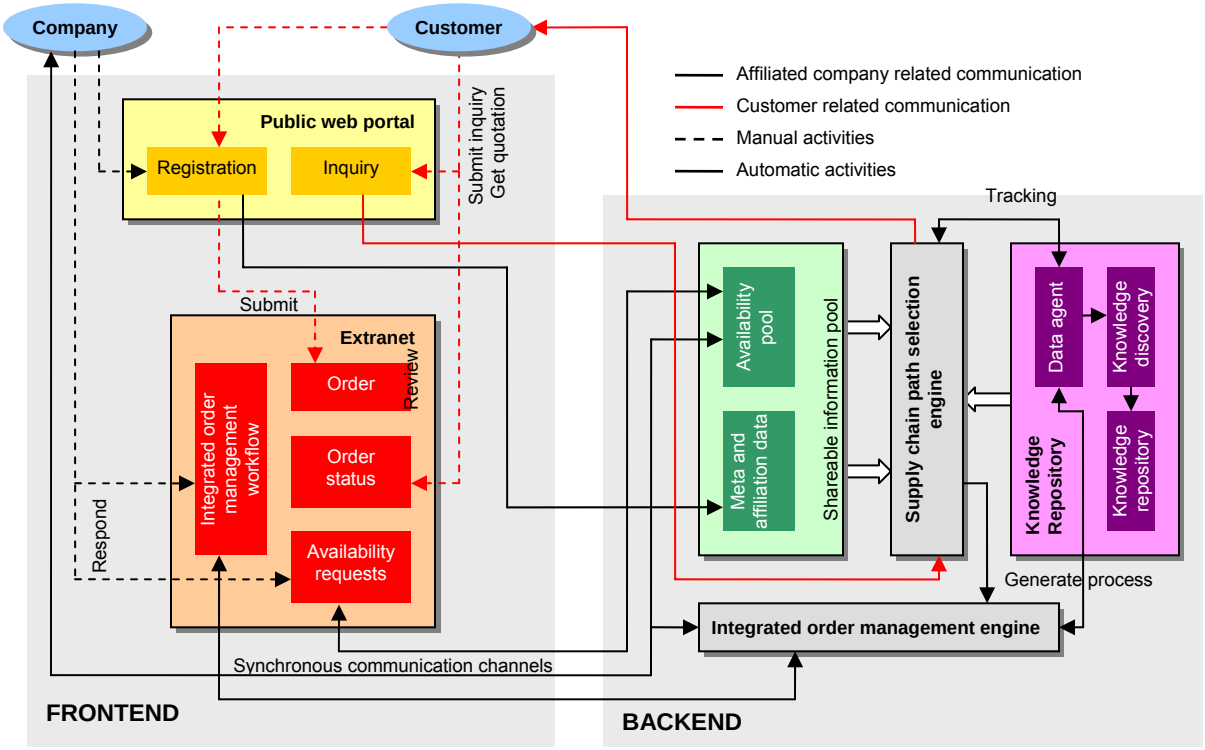

Figure 2. Web-based infrastructure for inquiry processing and integrated order management

Single point of access to all network information and services is web-based extranet. Extranet is the primary environment for submitting orders, tracking their status and coordination of asynchronous communication in collection of availability data. Also, it encapsulates workflow elements for asynchronous activities in integrated order management processing.

Extranet is integrated with public web portal, with functionality for registration of affiliated companies and submission of customer inquiries.

All activities related to supply chain selection are tracked by knowledge repository data agent.

Whether it is being done in a self-assesment basis or by a third-party consultant, initial evaluation rating of production competences might not reflect fully accurate measure of one competence's impact. Therefore, knowledge repository data agent is introduced for tracking selected supply chains and measuring efficiency of respective order processes. Known competence rating is validated against this measure, and correction is proposed, if necessary. Moreover, during inquiry processing, knowledge repository data agent validates and tracks the bill of material and establish references with all other selection process deliverables (manufacturing sequences, logistics issues, service levels, etc.), related to requested product lifecycle.

General purpose of knowledge repository data agent is to track all events and activities within a network during selection and integrated order management process, by monitoring an execution of supply chain path selection engine and integrated order management engine.

All event generated data is mined periodically by knowledge discovery agent. Purpose of this analysis is to recognize cross-references and relations between different data structures (for ex. fault handling and compensation scenarios), valuable for improvement of network and individual partners efficiency.

Supply chain network information pool

Basic pre-requisite for efficient and effective supply chain path selection is sharing of information among companies in the network. It is established by

implementing a network information pool - distributed, decentralised source of all information, vital for the selection of supply chain path.

Primary non-technical obstacles for establishment of network information pool are possible conflicts of interest and lack of trust within a network. In order to resolve these issues, companies involved in a network must be enabled to gain full control over their sensitive data manipulation and distribution through precisely defined, secured and controlled channels. Therefore, network information pool can not be a traditional data repository. Rather than that, it pulls data through dedicated channels, synchronously connected to company's ERP systems, or publish inquiries on specific availability information on network's extranet. SOA related technologies enable seamless and secure integration of these channels with company enterprise information system.

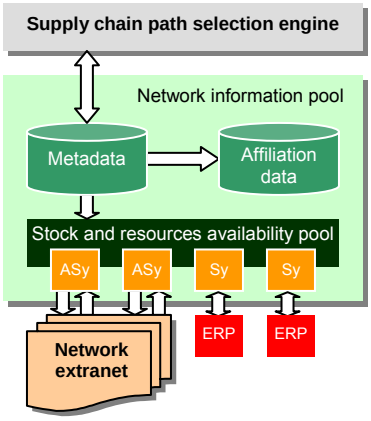

Figure 3. Coarse architecture of network information pool and its relations

Dedicated channels expose the status and behaviour of company's resources, relevant only for selection of supply chain paths. Exception from this rule is metadata – long-life information, describing competences, in general. Metadata is not extracted from ERP system, and does not include any confidential information. Therefore, a database with static metadata, as well as information on various aspects of networking and affiliation, will be included in a layer of network information pool, for the purpose of better performance in selection of paths. Database is designed on basis of competence networking ontology.

In order to enable real-time, accurate information to be used by network pool, it is obvious that it has to be connected to individual company's ERP system. Information needed for determination of optimal supply chain path, accessible by network information pool consists of:

1. **Metadata.** Array of customizable information related to general information on competences (location, ownership, product, resources, knowledge, etc.) availability, registered services for pulling availability information and their service contracts;
2. **Stock availability data.** Accurate Available-To-Promise (ATP) stock for all company products;
3. **Resources availability data.** Accurate schedule and scale for planned machining and human resources utilisation;
4. **Networking affiliation data.** Various aspects of networking and affiliation. For example, stock and resources availability data accessibility (synchronous or asynchronous communication), IPR issues, privacy issues, terms & conditions for affiliation, import & export permits, etc;

One of the most important assumptions for establishment of network information pool is on-time delivery of actual data, reflecting accurate availability of resources. In complex value chain paths, slightest alterations of the actual from the planned demand or supply can cause high deviations (Bullwhip effect), which cannot be compensated without significant negative effect on customer loyalty or manufacturing costs. Completeness and accuracy of data is basic pre-condition for feasible and beneficial implementation of ERP system. For example, several case studies shows that feasibility of MRPII implementation is achieved only if stock record accuracy goes 98% and beyond.

However, even though they could excel in certain competences on market, not all shops have ERP system installed. Solution for involvement of small and micro businesses without standard IT infrastructure could be implementation of virtual supplier hubs.

Supplier hubs are one of the methods for reducing the complexity of supply chain by introducing an intermediary who provide logistic service by storing components delivered by suppliers and forward these to the respective manufacturers [9].

Virtual supplier hubs follows this concept and represent third-party (commercial service) or joint ICT initiative of small and micro manufacturing shops, in implementation of integrated management of stock and manufacturing resources availability.

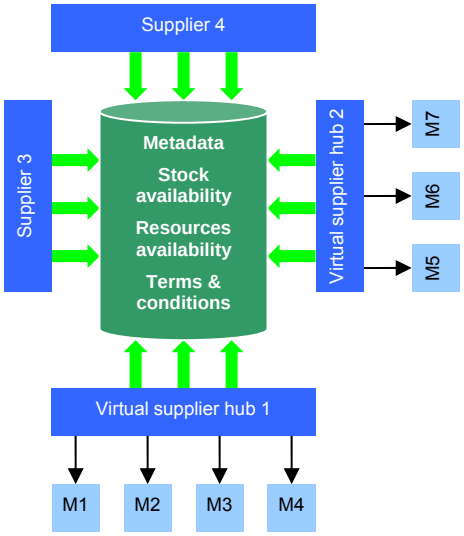

Figure 4. Supply chain network information pool with virtual supplier hubs

Concept of virtual supplier hubs is sustainable beyond the context of supply chain selection and integrated order management, and is feasible alternative for expensive ERP systems, targeted at the sector of small and micro manufacturing shops.

Another solution for involvement of small and micro businesses is usage of asynchronous, manually responded availability queries.

Stock and resource availability data are pulled from ERP system in synchronous manner, by default – request is followed by immediate response, with short wait state of the process, caused by network performance issue. However, this might not be possible in following circumstances:

A) Although company is willing to participate in network of competences, its security policy does not allow the inclusion of network information pool layer. This is very often the case in medium or large enterprises;

B) Company does not have ERP system implemented;

C) Network is temporarily down, or there is no permanent connection.

Whatever the case is, selection engine will use asynchronous communication for collection of availability data. Selection engine's request fullfillment is manually driven – engine generates a form for entering an response for availability sub-inquiry. Asynchronous communication means that process is not blocked in a wait state. Rather than that, it continues with availability sub-inquiries and calculates other supply chain paths based on collected data, until inquiry expiration.

This approach introduces several risks. First of all, supply chain paths, generated before inquiry deadline is expired, might not be optimal from the aspect of given constraints, which can lead to unsuccesfull bids. More important, each positive response of a competence node of the network, given to coresponding sub-inquiry should reserve the bided resources for certain period of time, during supply chain path selection and customer quotation elaboration. While it is not possible to urge the customer to shorten the period in which the company resources are reserved, and therefore - not available, other aproaches for resolving this issue can be implemented.

First, supply chain path selection engine must be enabled to recognise and invalidate analised paths which would lead to potentially unsuccesfull bids, during the process of current competence's availability assesment. By doing this, selection engine would be able to release reserved resources at earliest time possible. Second, legal agreement for network establishment must include precise definition of response time levels (for asynchronous requests) and consequences for breaking it. Finally, partners must be continuously encouraged to enable synchronous communication with a network information pool.

Inquiry processing and supply chain path selection

Process of supply chain selection is implemented on basis of SOA principles and guidelines. It is semi-automatic and consists of number of sequential activities, realised by synchronous and asynchronous web services.

Activities in supply chain selection, in order of their execution, are:

1. Inquiry definition;
2. Identification of required competences;
3. Partner qualification;
4. Quering competence availability subprocess;
5. Supply chains validation and generation of compensation paths;
6. Generation and delivery of the quotation

First challenge for design and implementation of supply chain path selection engine is inquiry or RFQ (Request-For-Quote) specification. Basic structure of RFQ is BOM-like. It specifies the bill of material for requested product quote, with support of UI (User Interface) tool. Inquiry is assembled and communicated through the system on basis on product ontology, which is stored in knowledge repository of web-based infrastructure for inquiry processing and integrated order management (Figure 2).

Product ontology is applied in order to assure the use of unified terminology and self-learning, extensible system, capable to recognise relations and cross-references in product lifecycle (design, quote and manufacturing) and save it for later re-use. Also, it stores generic production competences and their relations with product features.

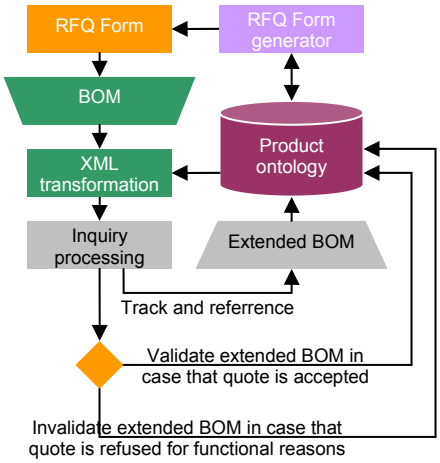

Figure 5. Process of inquiry definition and assembly of extended BOM

Process of inquiry collection is presented at Figure 5. RFQ form generator assists in a collection of information from a customer, in order to get precise requirements, necessary for further processing. Appropriate bill of material is assembled and transformed in XML-like structure, based on schema provided by product ontology. XML transformation is necessary, because XML semantics is the basic interoperability standard, particularily in SOA environments.

During process of supply chain selection, all its deliverables, such as manufacturing sequences, logistics and maintenance issues, required service levels, etc. are tracked and referenced to initially defined BOM of requested product. As a result, extended BOM is generated, integrated with product ontology and stored into knowledge repository.

With extended BOM as an input, specifically - relations of product features to production competences, supply chain path selection engine extracts required competences from product ontology and queries competence database in search of eligible partners. Eligibility of a partner is quantified and prioritised, with regard to level of validation of its competence and its rating.

In this phase, there is a significant risk of endangering the integrity of the process. In the earliest phase of engine lifecycle, product ontology data could be insufficient for generation of extended BOM with full specification of product features. Incomplete BOM could generate a fault in activity of identification of required competences and partner qualification. Therefore, a fault handling activity is introduced in process of supply chain selection. Activity of identification of required competences generates a fault in case that extended BOM is incomplete. Generated fault is handled by additional activity – inquiry validation. This activity is manual, and involves corrective human actions, leading to full BOM specification. Since selection process is instantiated only once, it is obvious that it will be in a wait state, for the time of duration of inquiry validation. Once BOM is fully specified, selection process will continue.

After eligible partners identification, availability queries are launched by selection engine. In order to avoid inconsistent quotation and preserve integrity of required product, defined by relations and references between different BOM elements, availability quering follows the structure of extended BOM. It is performed in a short living subprocess, with number of instances equal to possible number of relevant supply chain occurences. Each time two concurrent bids in one node of inquiry structure are placed, new instance of the subprocess is started and all previously set variables are copied.

Quering subprocess is generated by selection engine, and it orchestrates network information pool communication services, described above. Partners of the process are eligible partners, identified in previous selection activity.

Supply chains validation is automatic activity of rating of collected information and selection of the most suitable seenergy of resources and capacities, in context of fullfillment of customer objectives. On basis of competence rating, availability of resources and reliability of the partner, a number of competences are selected from the network information pool, quotation is generated and delivered to a customer.

It is obvious that management of the complex network of production competences involves significant level of uncertainty. It is induced by possible conflicts of interest, as well as the fact that effect of partner unreliability is multiplied in complex collaboration environments. Therefore, it is necessary to isolate possible risks to unsuccessful order fulfillment in the earliest possible phase. Although system tracks the order fullfillment process and establishes references between partners performance and their recorded competences, this is not enough for securing the order fullfillment success. Primary tool for risk management is identification and involvement of compensation and fault handling scenarios. They are identified from the bided resources and capacities in subprocess of

availability quering as its branches – secondary choices, not included in a final quotation.

Quoted price, deadline and other terms & conditions of the order are calculated on basis of selected primary path. They also include a margin, determined on basis of included compensation and fault handling scenarios.

Technical implementation of service-oriented framework

Web services are primary elements of SOA (Service Oriented Architecture) technology stack [8] – cutting-edge software technology for enterprise application integration and business processes implementation. They are software components which can, publicly or within precise boundaries, expose the status and behaviour of the company, by following the semantics of precisely structured and defined authorisations, requests and responses. Web services are tightly integrated with middle-tier of company's or supplier hub's ERP system, and expose their business logic through WSDL (Web Services Description Language) interfaces [10].

Although completely autonomous, in most cases, they are not self-sustainable. By using BPEL language [11] and appropriate commercial or open-source software tools, they can be orchestrated into manually initiated, manually driven or automatic, self-managed, business process.

Implementation of service-oriented framework assumes a rapid change in the way how things are handled, even when implemented at the top of some legacy ERP system. Service-oriented framework is not a substitution for legacy ERP system, but a layer for establishment of process-oriented style of business management and its daily execution. Since ERP system's objective is to support core business functions, its implementation can induce a significant threat to daily business continuity.

This threat is minimized when phased implementation of service-oriented framework [12] is used, graphicaly presented at Figure 6. This implementation approach is specifically tailored to the needs and business environment of small and medium enterprises, even though it can be applied as a practice in larger enterprises.

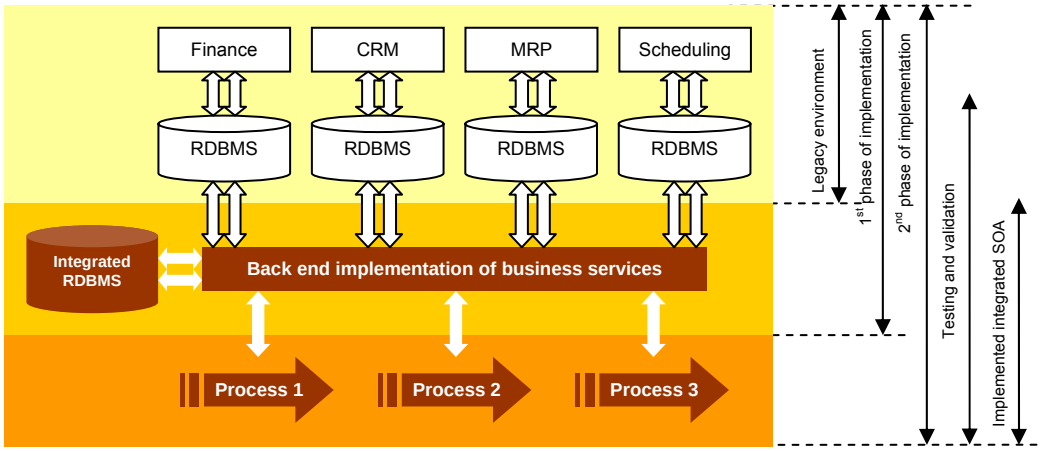

Figure 6. Phased implementation of service-oriented framework

In traditional static hierarchical supply chains, decision-making process in procurement of goods or services, as well as all participants and their responsibilities are known at system design time. However, this is not the case in integrated supply chain management.

Each path of network of competences is selected based on the current data from network information pool, at the time of supply chain selection. It is obvious that the partners of order management process are not known at the time of system design. Even process sequence can differ, due to specific order processing style of individual partner.

Therefore, it is necessary to establish a technical basis for real-time BPEL process generation and deployment. For this purpose, generic WSDL hub [13] will be used.

Its basic objective is to enable distribution of functional user interface, generated on basis of semantic interoperability model of web service, for use in business process management. However, some recent developments set the path for widening the scope of generic WSDL hub [12]. It is noted that its mediator functionality can be expanded in order to add more value to implementation of SOA environment in small and medium enterprise.

When external web services are used in process orchestration, which is the case in service-oriented framework for integrated supply chain management, their integrity is crucial factor of service quality and security. However, in order to be orchestrated by external process, WSDL interface of service must be updated with some BPEL-related, conversational elements. Basically, they describe roles in service orchestration and enable technical basis for definition of process partners. In this context, WSDL hub can be used for storing the information of web services partners in each of supply chain paths and real-time generation of intermediary interface with BPEL-conversational elements, which inherits third-party WSDL and mediates in forwarding of all requests and responses.

Conclusion

Current state of SOA standards and related industry experience provide a number of opportunities for implementing networking and integration approaches in wide range of circumstances. SOA technology stack is enabler for resolution of number of general integration obstacles, both technical and non-technical. Service-based orientation of a system design and orchestration technologies are critical for succesfull and rapid business process re-engineering and involvement of micro-management activities, even in small enterprises.

Dissemination of corporate knowledge, experience and resources followed by atomisation of production processes could create a structured environment for improvement of corporate market response, as well as its collaboration capacity. Expansion of this approach, facilitated by self-learning ontologies ensuring common understanding, beyond corporate boundaries would create a basis for more effective and efficient collaboration in supply chain management. Virtual detachement of individual partners excellence from their legal background would facilitate creation of a space of equal opportunities for managed participation in multiple supply chains. Its openness would have significant impact on network actor's market performance by enabling the discovery of unknown resources and potential for adding maximum value to existing products and services. It is obvious that small and micro enterprises, typically not capable to perform market research and business development activities would gain maximum benefit from such a network.

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