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Quality Monitoring and Composition in Information-Rich Services Supply Chains

Sai Zeng[1], Jakka Sairamesh[2], Mitch Cohen[1], B. J. Steele[3]

[1]IBM Research Division
Thomas J. Watson Research Center
P.O. Box 704
Yorktown Heights, NY 10598

[2]360Fresh, Inc.

[3]IBM Supply Chain
Poughkeepsie, NY 10532

Research Division
Almaden - Austin - Beijing - Cambridge - Haifa - India - T. J. Watson - Tokyo - Zurich

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Dr. Sai Zeng
IBM, T. J. Watson Research Center
Hawthorne, NY, 10532
{saizeng@us.ibm.com}

Dr. Jakka Sairamesh
360Fresh, Inc
{ramesh@360fresh.com}

Mitch Cohen
IBM, T. J. Watson Research Center
Hawthorne, NY, 10532
{macohen@us.ibm.com}

B. J. Steele
IBM Supply Chain
Poughkeepsie, NY, 10532

Abstract. In this paper we describe design methods and algorithms for service quality monitoring and improvement in dynamic service networks where business decision-making on product performance is dependent on the quality of services and information shared between the providers in the service network. We also present a methodology for composition based on diverse criteria and risk factors for continuous monitoring and improvement of the service network quality. The scenarios and results presented in this paper are based out of real industry engagements from diverse manufacturing supply-chains, where the primary manufacturer is increasingly dependent on the supply-chain for production, manufacturing and service delivery.

Keywords: Composite Services, Service Networks, Information Services, Decision-making, Matching, Supply-Chains, Optimization and Web Services

1 Introduction

This paper describes business composition strategies in a *service network consisting of multiple suppliers* to drive collaborative decision-making on purchasing and

performance measurements on manufacturing products. A service network implies a network of businesses in a supply-chain sharing services to design, build and improve upon products. Most of the literature in the academic and industry research groups [1][2][3][4][5][6][8][9] so far focuses on Web application driven services for accessing and composing heterogeneous applications managed by a single entity. Lately some research on business process services has been discussed [4][5][9][11] across multiple businesses.

Very limited work [12] has been done in understanding the role of a network of "*services*" [8][10][11] for decision-making (e.g. supply-chain purchasing), and not much technology has been developed to compose these diverse services based on business or technical (IT) needs to enable complex decision-making (e.g. improved purchasing or product redesign or product monitoring). We present scenarios from a real-life case-study based on supply-chain collaboration for product improvement, where information being shared is private and sensitive. The products being discussed are automotive vehicles or electronic products, where multiple suppliers can be selected and composed (e.g. Web Services composition) during system design time or runtime to enable purchasing parts or components or services in a supply-chain. This paper illustrates the need for distributed monitoring and composition of services and products from suppliers, and feedback to revise compositions. By service composition we mean combining business and IT services offered by the suppliers in the network to satisfy the business need.

1.1 Challenges

Over the last decade, large enterprises have witnessed tremendous increases in production and quality issues due to increased product complexity, dependency on the supply-chain, information disaggregation, and process disconnections with existing legacy applications. For example in Electronics and Automotive industries, hundreds of suppliers and thousands of dealers form the value chain for design, production and delivery of complex products and services to end customers. If a product fails, then identifying what went wrong, gathering and sharing evidence, determining the responsible party, purchasing new parts, and correcting future purchasing decisions are challenging. Mistakes made in selecting the product components from the wrong suppliers can be costly with further risk. In the Automotive Industry alone, due to part and subsystem failures in vehicles (in use), the costs of Warranty have risen to over 30 Billion Euros per year across the globe. This overall cost will continue to rise till manufacturers and their partners find a way to leverage services online and collaborate to fix the product quality issues as quickly as possible and take preventive actions. We outline challenges in designing a dynamic composite service based on the services offered by two or more suppliers in the service network.

The first challenge: Understanding the nature of business relationships (e.g. contracts or SLAs - Service Level Agreements between suppliers and manufacturers), service and IT integration capabilities in the service network is vital in decision-making. The challenge lies in indentifying the right network partners (e.g. suppliers) and their products based on multiple criteria, which include costs, delivery performance, non-conformance rates, taxes, reliability, performance, supplier value, financial stability and others.

The second challenge that needs to be addressed in the service networks is measuring, monitoring and correlating business events related to service failures from the supply-chain and feeding them back into new purchasing decisions. The challenge is to collect and correlate data from the network entities across multiple time-periods.

The third challenge: Various criteria need to be used to dynamically compose information and applications during design and runtime across multiple service network entities (e.g. suppliers given) that those entities have registered their services through a Third-party registry or directly with the manufacturer. Suppliers can change their service signatures or interfaces and this can result in costly design-time composition.

2 Case-Study Details

This section describes a case-study of a service network from the automotive industry; this example will be used throughout this paper. The automotive service network contains three main types of businesses: (1) the manufacturer (OEM), (2) the dealers, and (3) the suppliers; their purpose is to create, sell, and service vehicles (e.g. cars or trucks or small vehicles). The manufacturer (in Figure 1) sells multiple products through dealers, who are responsible for selling the vehicles to consumers and handling repairs. The manufacturer procures subsystems and parts from a multi-tiered supply-chain as shown in Figure 1. Each vehicle is assumed to consist of subsystems, which contain parts (belonging to commodities). Purchasing is done by the manufacturer and local plants based on several criteria. Each local plant makes their decisions on purchases based on delivery costs, quality, reliability and others. The goals of the manufacturer are to enable better purchasing decisions based on historical information, product failures and high costs of recovery.

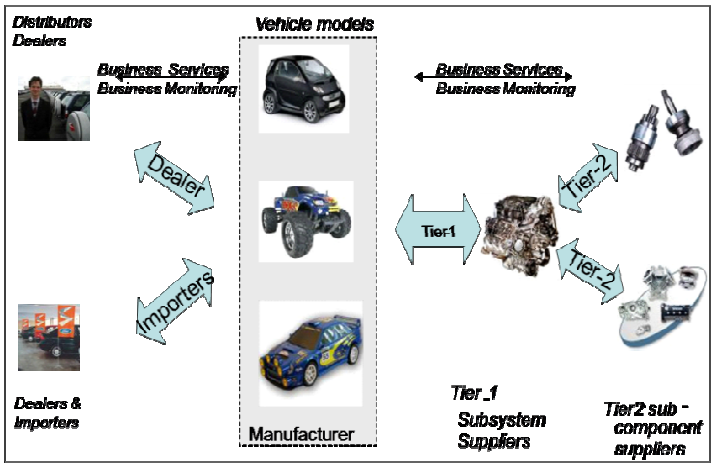

Figure 1. Service Model

Purchasing Concerns: The manufacturer in this case-study (Figure 1) is concerned about recovering from mistakes in selecting suppliers and purchasing faulty parts. The manufacturers are concerned about early identification and rating of product failures (e.g. battery or transmission or electronics failures) and when they are reported by dealerships or consumers or suppliers (e.g. Tier-1s).

Evidence gathering: The manufacturer has to gather evidence and prove using current information and past history the responsible component (s) and party for the failure. If the failure is classified as being supply-chain responsible (e.g. non-conformance of parts or misfits with embedded electronics), then the suppliers will be notified, and appropriate action will be taken to find alternate suppliers or improve existing products.

Improvements in Services Composition: The manufacturer establishes a model of collaboration with the suppliers in the supply-chain to enable sharing of failure information, evidence of failure, validation results, non-conformance issues and future purchasing decisions. The manufacturer and suppliers have prior agreements on using contracts and SLAs. Web Services for interaction and behavior are specified with appropriate security and privacy in place for enabling composition.

2.1 Supplier Performance Evaluation and Sourcing Decision

In this use case, a manufacturer in the automotive industry (of vehicles) is concerned about making the right purchasing decisions by including supplier performance feedback into partnership, purchasing and composition decisions. An accurate supplier performance evaluation is dependent on good indicators include not only the information related to products provided by the suppliers (e.g., product quality and on-time delivery), but also the information related to the supplier technologies, capabilities (e.g., ISO certified, capacity), processes, organizations, etc. Such information reside in disparate data resources each of which are owned by different

organization branches within the OEM such as procurement, quality, plant, design, warranty, owned by suppliers and sub tier suppliers, and owned by third parties such as auditors and dealers. In Figure 2 we show a supplier performance evaluation system which includes a network of services. This providers a capability to allow stakeholders to search for a particular commodity, all parts under a particular commodity, a particular supplier, suppliers associated with a particular commodity or part, or all commodities or parts supplied by a particular supplier.

Distributed Services

We consider a distributed collection of services in the network of suppliers as shown in Figure 2. A **traceability service** allows a part at any stage of the lifecycle to linked to the equivalent and related entities in other stages of the lifecycle. For example, this service allows identification of parts and their owners, parts and their suppliers by product lot numbers, revisions to be identified to confirm effectiveness of supplier changes, parts and associated products (for instance, Vehicle Identification Numbers, VINs, on a car), and the parts and the suppliers in a given product. With this service, it is easy to find both the right root cause and the responsible party for a quality problem. The quality containment process is implemented in a faster more effective manor with a tighter control of costs. For example, an expensive massive recall is avoided and replaced by a selective recall on a set of carefully selected vehicles

The evaluation service is used to prepare inputs for the scoring system after all the necessary information is gathered from the various systems. The input includes objective and subjective information from supply chain processes, manufacturing processes, and warranty and service processes. This set of information represents current and past facts.

A survey service is used to gather input from stakeholders and customers on supplier performance. The data gathered is often called the “soft” or subjective metrics. Subjective metrics are typically those that measure intangibles like trust, confidence, attitudes and satisfaction against supplier quality, technology competence, process capability and so on.

The scoring service is the core component in support of this particular use case. It aims to identify the best suppliers for specific parts and/or commodities. The identification is based on the scores computed from multi-level criteria.

The **alert servic**e designed to monitor business events warning stakeholders of abnormal behaviors. This system uses rules to monitor business events, setup threshold or boundaries for abnormal behaviors (e.g., threshold on number of failures for a specific part during a particular duration). The awareness of abnormal behavior goes through two stages, a warning stage and the alert stage.

Finally, at the backend of the system, a **service data warehouse** consolidates supplier performance data sources throughout the product life cycle. Example data sources are systems measuring conformance, issue management, containment, purchase orders (PO), and warranty spanning supply chain processes and manufacturing processes. These are the example data sources we have consolidated, but it by no means represents all data sources for performance evaluation. These sources provide a good reference on what type of information an OEM should consider for the evaluation process.

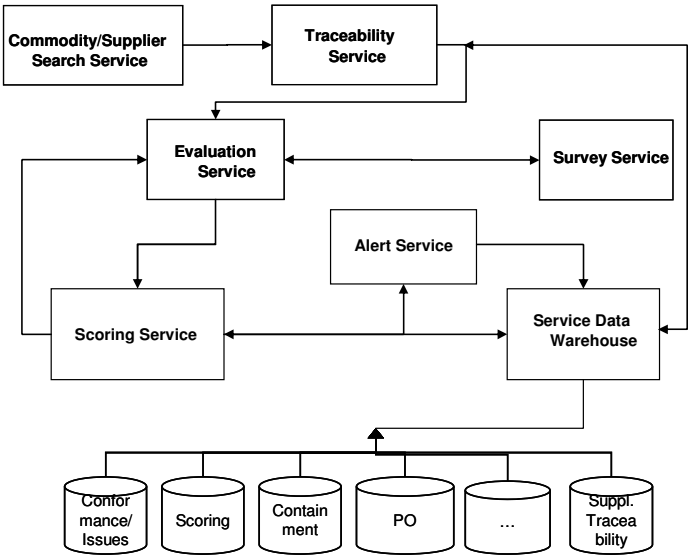

Figure 2. Distributed Services for Manufacturing Traceability

An example supplier performance evaluation process enabled by those services is shown in Figure 3.

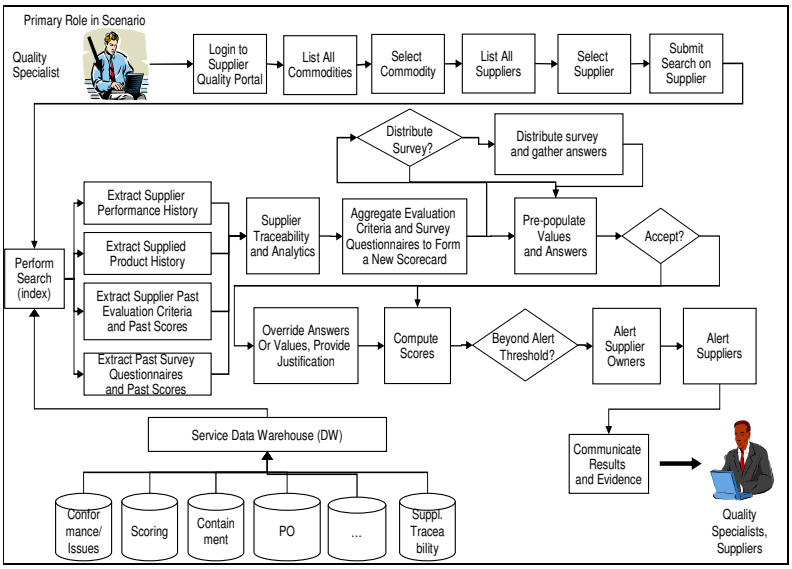

Figure 3. Supplier Performance Evaluation Process

2.2 Business Use Case 2 – Selective Recall

Enterprise supply chains and business processes change often. It is common to have multiple vendors participate in various parts of the lifecycle of a product, where thousands of parts/products/processes identification numbers (IDs) might be used at various stages of the process by different participants. With such complexity, it is difficult to associate a supplied part with its early stage design part and related information. A replaced part cannot be linked to the original part after service. If there is any quality issue with a part, during aftermath quality containment, it is impossible to identify how many and which final products have been impacted due to this quality issue. In the automotive industry, it is not surprising to see an announcement of massive recalls which involves thousands or even millions of cars, despite the fact that only small fraction of recalled cars are indeed impacted.

The solution to avoid massive recall is selective recall for only affected vehicles. In the use case as shown in Figure 3, a supplier quality specialist receives frequent complains about quality issues of a part. The quality specialist carefully examines the quality issues and decides to recall the parts for replacement. A traceability service is invoked to trace the part number to the processes, responsible parties such as suppliers, and more importantly, the impacted final products. A list of VINs (Vehicle Identification Numbers) is obtained and a recall is issued to the affected vehicles. The details of services can be found from previous use cases except collaboration service. In selective recall, manufacturer, suppliers and dealers have to work together to make decision on selective recall and aftermath recall and service actions. Collaboration service provides platform to allow information and evidence exchange among these parties therefore lead to consensus on the recall.

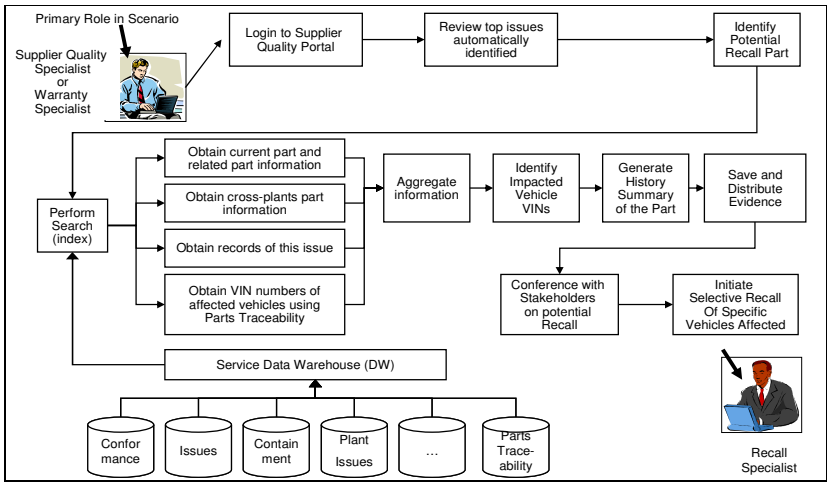

Figure 4. Selective Recall Process

3 Service Quality System

In this section we present the Service Quality system implemented for real engagements for doing services selection, integration and composition in order to improve manufacturing product performance and supplier quality. The service system monitors both the business services and IT services offered by the suppliers over the Internet. In Figures 5, 6 and 9 we show screen shots of the real functioning service quality systems connecting information from multiple suppliers within a large data warehouse system.

3.1 Services for Composition

Manufacturer requires a system to compose purchasing applications across multiple suppliers (as shown Figure 1). The expected technology and service requirements include the following:

- The early identification of potential safety issues by looking into information across multiple sources from multiple entities (e.g. suppliers and consumers). Information can be shared as services across the supply-chains.
- Composition of Supplier Web Services during design-time and runtime based on SLAs and other contract terms and conditions. The composition is not just based on the SLA values, but also based on business service state, previous failures, recovery state and improvements.
- Composition is based on criteria such as performance of services by suppliers, supplier scores, costs and others. In Figure 8, we show the composition process for enabling a new business service across the service network of suppliers.

3.2 Alert and event Services

The manufacturer does analysis of product failure alerts generated by a detection system that integrates information from multiple information sources within the business and across the supply-chain of suppliers. For each part-failure the manufacturer identifies the source of the failure and begins an investigation into which supply-chain supplier (s) contributed to the faulty part. The analysis requires information about the part history, failure history, supplier history and analysis of similar failures. The alerts (Figure 5) enable future purchasing decisions to be based on current failures and past issues on parts and supplier performance.

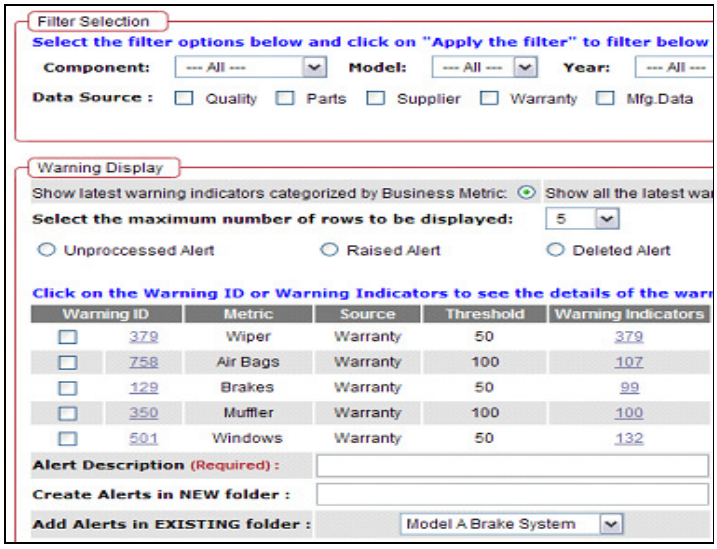

Figure 5: Alert service for monitoring products and suppliers

3.3 Product information services

An internet or web-driven service collaboration is set up between the experts in the manufacturing company and engineers at the suppliers on the specifics of the part defects and the corresponding impact. The collaboration enables sharing of failure information from the manufacturer to the suppliers from the Bill of Material and product data systems. Information (Figure 6) about the design and part quality processes is shared between suppliers and manufacturer based on the specification provided.

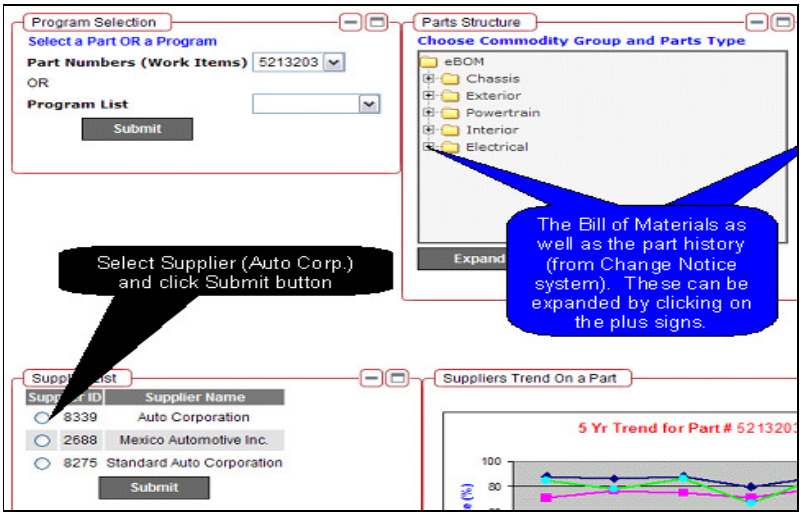

Figure 6: Search Service for product documents (screen)

3.4 Collaboration services

Risk of future product failures based on current part defects and component failures is calculated to assess the next course of action, which could result in a stop in production to limit the number of risky vehicles or a collaboration set up with the suppliers to identify the source of the problem immediately and take action on finding alternative suppliers or collaborating with the current selected suppliers to redesign or improve the parts that were found defective.

4 Performance Driven Composition

In Figure 7, we illustrate the main components of a system and methodology of that system needed to enable composition and integration across the supply-chain.

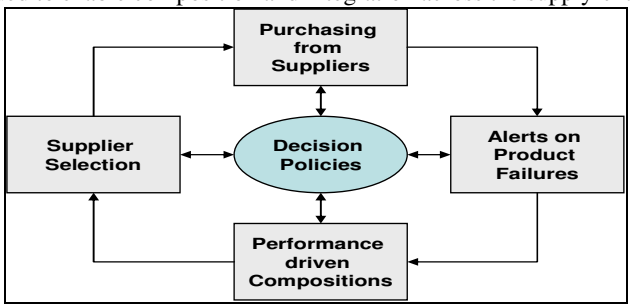

Figure 7: Monitoring Methodology

The methodology illustrates four major service components within the service network. These components can be implemented physically across multiple businesses in the service network or multiple divisions within a business or a combination.

Selection process:, which needs to be done across the enterprise (across supply-chains and value-chains) at a coarse and fine-grained level.

Purchasing composition: modeled as new service by itself to enable alerts from multiple sources within and across the Enterprise. Across the Enterprise alerts can arrive from dealerships (e.g. Automotive) on product failures or consumers or suppliers.

Alert assessment: to analyze current cost, future cost and risk to profitability of the company based on bad decisions.

Revised composition: based on performance metrics, new service composition is done with new or alternate suppliers. All of these components are inter-connected by the manufacturer as a ***composed application*** for monitoring, measurement, analysis and corrective action.

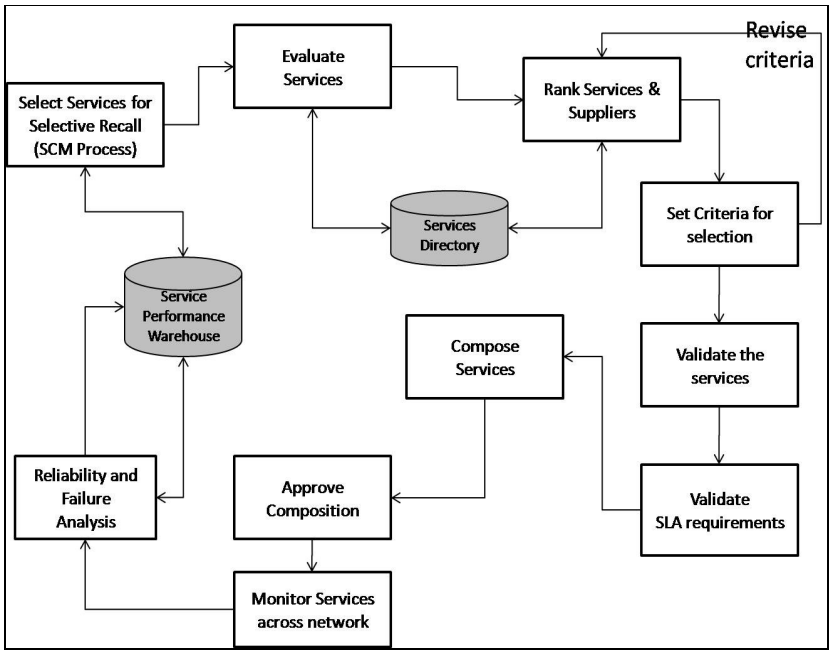

Figure 8: Composition Process

4.1 Design of methods for criteria and optimization

In Figure 8 we illustrate the decision-making criteria on creating a new composition on services (both Web services and Business Services) is based on several performance driven criteria and parameters. Some of the criteria are the following

- Risk and cost of selecting the service from the network of suppliers

- Delivery performance of the service (from past history)
- IT services reliability of the supplier
- Lead time requirements
- Cost of labor and facilities
- Taxes and transfer pricing

In the box below we show an XML representation of the service performance definition (as offered by the suppliers). A data warehouse of the service performance is maintained at a central location (e.g. Manufacturer) for evaluation and selection. The performance of the suppliers and services offered are continuously monitored and analyzed for future compositions of services offered by the suppliers.

```
<ServiceCriteria>
        <ServiceRef>  SJUY0913435 </ServiceRef>
        <ServiceName> SHJFH8934 </ServiceName>
        <ServiceProvider> Parts Supplier </ServiceProvider>
        <ServiceStart>  09-06-2008 <ServiceStart>
        <ServiceMode> Daily </ServiceMode>
        <SecurityLevel> High </SecurityLevel>
        <AutomationLevel>  Medium </AutomationLevel>
        <SLACode>  SLA:3445KJDJLK </SLACode>
        <SLAType>  PayPerTransaction </SLAType>
        <InformationSource> ERP System</InformationSource>
        <Reliability> Tolerance 1 failure per 10,000 transactions</Reliability>
</ServiceCriteria>
```

The selection criteria, weights, the targets and expected values are listed Table 1 below. The selection criteria include the IT criteria as well, which are driven by the SLAs in terms of performance of the service when requests are sent by the manufacturer to the supplier on delivery dates for products or product specification of product performance numbers. The column on weights specifies the criticality of the criteria in the selection process (Figure 9). The reliability of the IT services becomes an important parameter in future selection of the supplier from the Service Network.

Business and IT Criteria	**Weights (scale of 1-10)**	**Target**	**Values**
Cost	High	Threshold (< 80% of previous cost)	70% below current cost
Reliability	High	Threshold (< 0.01 % failure probability)	Less than 0.01 percentage
Failure rates	High	Threshold on failure count per 1000 components	Less than 2 per thousand failures
Financial stability	High	Threshold (over 20% of sales)	Profit over sales percentages

Overall Performance	High	Performance score Over 99 (scale of 100)	Scorecard score (over 99)
IT reliability	Medium	Reliability over 98% in service uptime	Downtime risk or 1% of the time (per month or per year)
IT performance	High	System performance (multiple users)	System values (over 200 simultaneous users)

Table 1. Examples of Selection Criterias

Figure 9: Scoring criteria and performance screen

5 Monitoring Services

5.1 Event Services

As described before, the goal of the system is to enable modeling and monitoring of critical events. Figure 10 illustrates a functional view of the monitoring and composition engines. The main modules are: (1) Decision Engine, (2) Monitoring System, and (3) Composition engine. The decision engine is responsible for integrating event information, running analytical models and providing the best suggestions on decisions for composition.

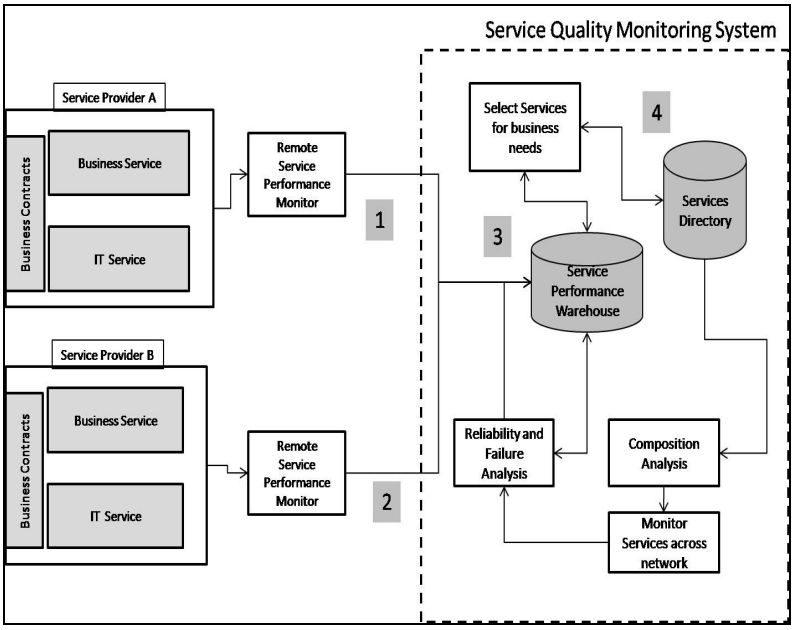

Figure 10: Remote performance monitoring

The Monitoring System is a distributed system with components running in each business in the service network. These components are continuously monitoring and measuring the performance of physical product and the IT service offered by the service network businesses. The main role of the monitoring engine is to execute both qualitative and quantitative types of analyses on behalf of the stakeholder and send the results to a decision-making entity. In this case, the decision-making entity will be a purchasing manager of the manufacturer who is looking to use feedback from the products in use on whether to improve or correct the purchasing decisions.

5.2 Monitoring Services

Figure 10, shows the structure of the overlay network across businesses (enterprises) for monitoring and measurement at coarse and fine-grained levels.

The first layer (remote site) is corresponding to enterprises that are involved into a service network, and each node represents one enterprise (for example, a manufacture company) or a division within an enterprise. At the second layer (service quality system), each node corresponds to a capability group such as process within an enterprise. Monitors can be deployed at each of the providers. Each monitor that is deployed at lead level captures the real-time behavior of each unit in the service network. The monitoring results for all the nodes are transferred to the data warehouse as shown in Figure 10 for further processing and improvements in composition.

5.3 Composite Alert and Analysis Services

In Figure 8, we illustrate a workflow and composition model based on the case-study in Section 2. The services are offered by multiple divisions within an organization or enterprise to enable failure identification and corresponding decision-making to improve purchasing. The alert, event and notification services are done in a distributed fashion as critical alerts and corresponding data (as shown towards the left of Figure 8) can come from dealers, consumers, suppliers, sensors and other specialists in the ecosystem for triggering a new investigation into the failure, and subsequent collaboration on identifying product failures. In the Figure 8, the functional representation of the Event and Alert services is shown, but in reality these services are distributed across a collection of business entities.

The alert, event and notification services are done in a distributed fashion as critical alerts and corresponding data (as shown towards the left of figure 6) can come from dealers, consumers, suppliers, sensors and other specialists in the ecosystem for triggering a new investigation into the failure, and subsequent collaboration on identifying product failures. Once the events and alerts are processed by the manufacturer, the corresponding decision-processes are triggered manually to correct the issues and recover from the failures.

6 Conclusion

In this paper we presented a structured methodology on performance based service composition in a dynamic service network consisting of manufacturers, suppliers, third-party service enablers and dealers. We presented scenarios from a real-life case study based on past client engagements on improving purchasing decisions based on feedback and alerts from a network of suppliers. We outlined a list of criteria for enabling both design-time and runtime compositions of business and IT services based on costs, reliability, quality, delivery and others. We also illustrated a methodology and algorithm for doing service monitoring and composition across multiple suppliers in a service network, where a supplier can be selected or deselected from a composed application. The algorithms were implemented as a part of a real-solution for validation. We deployed a working service quality system to measure, monitor and improve upon compositions for manufacturing procurement.

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