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Proposal of Industrial Product Service System for Oil Sands Mining

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Abstract—**As new materials, new technology such as cloud computing and new configurations for the manufacturing enterprise emerge, the distinctions among mechatronics, manufacturing, and service industries become blurred. Consequently, it is expected that the definitions of Industrial Processes become even broader. Outsourcing industrial processes is a common practice and also strategy weapon for many companies to reduce costs and enhance the utilization of internal resources forming core competencies. This paper presents the concept of an industrial product-service system for oil sands mining (om-iPSS) based on the utility enhancement of oil sands mining systems. The intelligent technologies such as the cloud computing are proposed as embedding knowledge in the outsourcing-oriented om-iPSS for the whole life cycle of production process. As a result, the om-iPSS with advanced characteristics such as distributed, intelligence, adaptation and self-organization is developed in which a novel approach for enabling individualized and highly-customized production is proposed. Architecture is proposed to enable the om-iPSS from the aspects of both hardware and software. Key techniques for implementing the architecture are discussed for illustrating the use of the om-iPSS concept.**

Keywords- industrial product service system, oil sands mining system, industrial process, service, system engineering

I. Introduction

With the high carbon emissions from oil sands mining, a sustainable solution is of great emergency for reducing the impacts on natural capital and ecosystem as well as cutting cost of companies. Also the challenges of intense international competition and market globalization have placed enormous pressure on oil sands mining companies to improve efficiency and reduce operational costs. These challenges have forced managers to adopt tools, methods, and concepts that could stimulate performance growth and minimize losses and errors, and to utilize resources effectively toward making the oil sands mining systems a high-performance manufacturing plant. Nowadays, maintenance is acknowledged as a major contributor to the performance and profitability of systems. Many researchers have focused on the monitoring and maintenance sector to solve this problem, since system failure can lead to costly stoppages of a company's operation, which may result in low human, material, and equipment utilization. For instance, Mahmood explored the plant maintenance management system that has been used by giant oil and gas company in Malaysia [1]. Dey presented a risk-based decision support system that reduces the amount time spent on inspection pipeline health [2]. However, these ideas are lack of the perspective from the life-cycle of product, which is of great significance for the sustainable production.

The soul of industrial manufacturing no longer lies in making products but extends to the systematic processing of information and resources to create better service and more value for customers [3]. Recently, as a new understanding for business relationship within the Business-to-Business market, Industrial Product-Service Systems (iPSS), has been proposed as the means of starting the tertiarization of the industry sector. An Industrial Product-Service System is characterized by the integrated and mutually determined planning, development, provision and use of product and service shares including its immanent software components in Business-to-Business applications and represents a knowledge-intensive socio-technical system [4]. And there are also lots of successful examples which have changed from product sell into providing solutions with integrating tangible artifacts and intangible service. For instance, Shannxi Blower Group (ShaanGu) is specialized in manufacturing axial compressors and turbo machineries. Before 2001, the company only provided pure products to its customers and its products were easy to be imitated. And the competition is usually focused on the price and quantity among these enterprises. This kind of competition leads to lower price and narrower profit accordingly. To change this situation and find a new way for sustainable competitive advantage, ShaanGu thus determined to transform its manufacturing mode from traditional product-driven pattern to novel system-integration and service-oriented mode. As a result, its' annual turnover increased from RBM 400 million to RMB 2.5 billion with an annual profit increase rate of 89% during 2002 to 2005.

As shown by above case, service-oriented companies can provide customers by with individualized and highly-customized service. The service has been highlighted that product characteristics and service activities influence each another [5], so service designers should consider how to integrate and balance them. How to design and operate a successful, sustainable customization and personalization iPSS and what methods to improve iPSS design becomes a hot topic recently [6, 7]. At the same time, some new technologies have emerged, and have been widely applied in various fields, such as advanced computing models and technologies (e.g. social computing, cloud computing, big data, ubiquitous computing), service-oriented technologies (e.g. service-oriented architecture, semantic web), internet of thing (e.g. radio frequency identification (RFID), wired and wireless sensor network, embedded system), and so forth. These technologies, especially the cloud computing technologies, are the enabling force for effectively addressing the above mentioned changes in various industries.

In this paper, combing the above mentioned new technologies and existing theories and technologies of current enterprise information, this article describes the structured engineering process to design and run the Industrial Product-Service Systems for oil mining (om-iPSS). Thus the concept and architecture of om-iPSS are described. Key techniques for implementing the architecture are discussed for illustrating the use of the om-iPSS concept. om-iPSS are not only a new product understanding but also a paradigm shift for the design and operation to a customer-provider-relationship in which both partners gain a win-win-situation. But there are not only the two companies involved that represent the customer and the om-iPSS provider but also additional suppliers form a network that is responsible for all om-iPSS product and service shares for all om-iPSS life cycle phases.

II. CONCEPT AND ARCHITECTURE OF OM-IPSS

As shown in Figure 1, om-iPSS is the integration of a series of oil mining equipment and services into a value added stable oil&gas productivity solution. An om-iPSS provider has to design and operate systems that are adaptable for different customer situations. One challenge for the design and running is that details of the product and the service shares can vary during the service life cycle. Thus in the service process, the service provider are supposed to have the ability of transfer life cycle demand and implementation data into the service knowledge, and thus in return to provide customer with better and sustainable optimized product service.

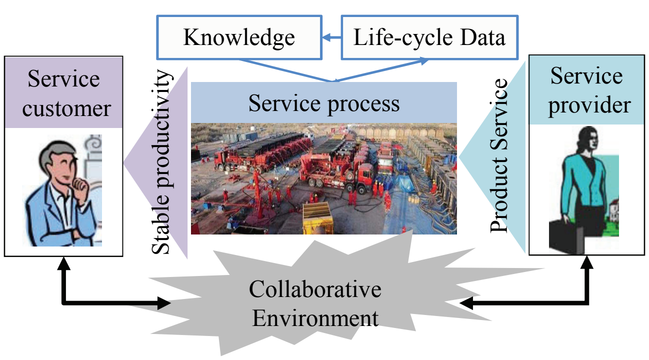

Figure 1. Concept of om-iPSS.

om-iPSS can be defined as a kind of specialized production driven, mass resources self-organization based, and service-oriented intelligent oil ining mode. By employing the ICT such as service computing and cloud computing for identifying and channeling the complex interaction between various equipment providers, it aims to realize the proactively and on-demand use of manufacturing resources throughout the service network. It enables the manufacturers and providers to finish customized partial or the whole lifecycle production on the basis of an on-line, self-organizing and interaction-enable mechanism.

om-iPSS are a new system thinking that differs from the traditional paradigms such as leasing, after-service, and Maintenance, Repair & Operations (MRO) as shown in TABLE 1. New engineering methods, especially for the design and operation of om-iPSS, are necessary to create such solutions. With the integrated products and services mutually determined by provider and customer, om-iPSS enables a life-cycle proactive solution to create a stable productivity of oil&gas, which naturally formed an added value.

TABLE I. TYPICAL SERVICE PARADIGMS

Service Paradigm	Product ownership	Service mode	Service target
om-iPSS	Provider/ Customer	Proactive	Life cycle stable productivity
Leasing	Provider	Passive	provide customer oriented product
MRO	Customer	Proactive	Make product high efficiency
After service	Customer	Passive	facilitate users' application demand

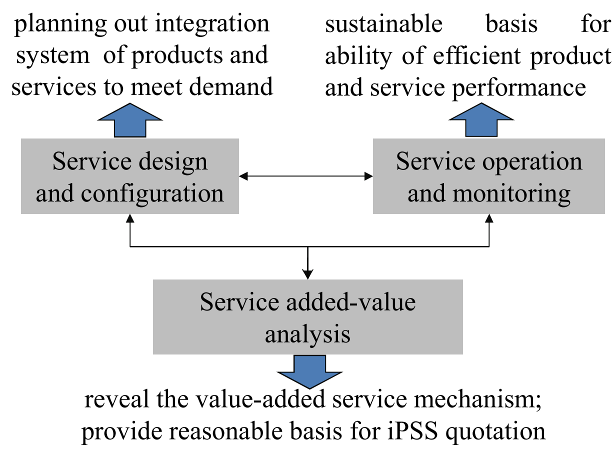

Figure 2. Architecture of om-iPSS.

The architecture of om-iPSS is shown in Figure 2. Characteristic for the new model is the strong emphasis on the design, running, and added-value analysis definition. Firstly, the phase 'Service design and configuration' is addressing new design approaches for an integrated design of products and service processes on a system level, the goal of which is planning out integration system of products and services to meet demand. The configuration on the value level underlines the customer orientation even in late development phases. Secondly, the 'Service operation and monitoring' is a straightforward orientation at product and service quality issues and supporting the application of domain specific design methods in the later phase. It's a sustainable basis for the ability of efficient product and service performance. Finally, the 'Service added-value analysis' highlights the influence of mutually interaction in the process of services and the value-added service mechanism. It also provides the service provider with reasonable basis for om-iPSS quotation. The possibility to use feedback knowledge from the delivery and operation phase is illustrated by bi-directional arrows between two. The following described engineering logic and methods are supporting the different system states for the design and running of om-iPSS.

III. DESIGN AND CONFIGURATION OF OM-IPSS

Most oil mining operators ensure that during the design stage, safety provisions are created to provide a theoretical minimum failure rate for the life of the oil mining systems. The om-iPSS design is the basis for the following service running. Service functions, objects and processes have to be further detailed into the customized product and services shares of the om-iPSS. While the majority of developers are familiar with developing products, software or e.g. production processes the systematic development of services especially in the context of iPSS is still not prevalent. Hence, the methodology of generating services shown in Figure 3 aims at supporting a developer during a customized om-iPSS's concept development in defining the right services necessary to realize a certain value proposition. Such a generation is subdivided into four major sections referred to as follows:

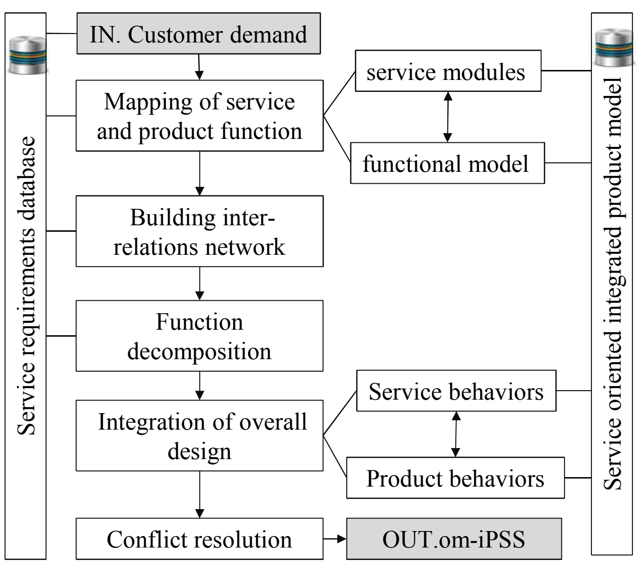

Figure 3. Design methodology of om-iPSS

A. *Mapping of service and product function*

The functions that the om-iPSS has to achieve are taken from the functional model, which are associated with those product service modules that meet at least one specified function description. Product-service modules that achieve the particular function are mapped for each required one. Solution sets are pre-created that contain alternatives of features and implementations for the required functions.

B. *Building interrelations network*

The components of product-service modules and function models are correlated between two different levels. There are interrelations being made between product shares and service shares during configuration. The interrelations with product and service need a uniform way to be treated. After solution sets have been obtained with function product- service module interrelations, the interrelations network have to be matched against the om-iPSS requirement specifications.

C. *Service function decomposition*

Customized values are allocated to each function thus reducing the solution sets. A decomposition results from the subsequent adjustment of the solutions regarding their interrelations among service models and function models.

D. *Integration of overall service modules*

Considering dependencies among each other, an IT-supported generation of services are in great need for the systematic support of an om-iPSS developer with regard to the integration of services into a product.

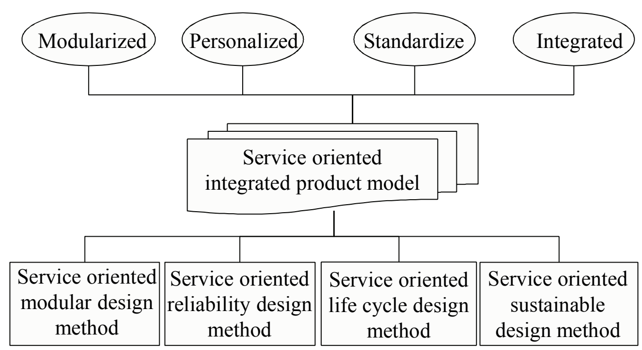

Figure 4. Service oriented product model of om-iPSS

E. *Conflict resolution*

This operation process may have the result that the originally designed concept does not coincide completely with the obtained solution. Therefore, compatibilities, feedback about necessary extensions, and conflict are supposed to be solved in the concept model stage.

Figure 3 describes the design and configuration process that is used in the assistance system for the configuration of om-iPSS. Through the IT-supported designing of services, the om-iPSS developers is efficiently archived as well as reused. The consistent integration of the proposed design approach as shown in Figure 4 into an om-iPSS development supports the transition from a product manufacturer into an om-iPSS provider.

IV. OPERATION AND MONITERIG OF OM-IPSS

As shown in Figure 5, running of om-iPSS is a combination of all technical, administrative, and managerial actions during the life cycle of oil sands mining system intended to keep it in or restore it to a stable oil&gas productive state in which it can perform the required function. An organization can have its customers build confidence in it by having uninterrupted flow in oil&gas productivity. The operators are developing an organized operation knowledge and policy based on data analysis and other existing practices and experiences. Existing policies are not sharply focused from the point of the life cycle. The basis for selecting health monitoring and inspection techniques is not very clear to many operators. Therefore, to help operators for a more clearly focused inspection and monitoring, techniques listed as below should be formulated.

A. Self-organizing of equipment resource

To create dynamic maps that pinpoint where resource and capability reside and to track new data in real time, the most effective way is to engage a carefully mapped network of mining resource on specific attribute. For a mining service provider, there is a significant phenomenon that some process of the mining task would be outsourced to other providers if the enterprise cannot handle it or considering to decreasing the special cost of running it as soon as insourcing an oil mining task. Classical hierarchical management structures often don't work effectively when directing the activities of this kind of loosely-coupled network, which is a highly complex, dynamic, and autonomy rather than stable structure due to the conflicts of local and overall interest.

Thus, to realize the online and real-time organization in om-iPSS network, the key issue is that collects and channels vital, accurate capability and information to eliminate the need for extensive searches of traditional databases inside the workshop of a manufacturer. This real-time information leads to adjustments of manufacturing and strategy. When enterprises can easily disseminate production information even across the entire om-iPSS network, enterprises can be aware of problematic situations before they occur and also want to ensure they can detect violations and defects as quickly as possible before they become an actual problem. This has great implications for real-time oil mining, as it frees up manufacturers to work on more value-added activities rather than waiting for the completion of another phase of the production.

B. Equipment fault predication

Equipment fault prediction is a necessity for realizing the maintenance before shutting down. It provides proofs for decision making and reduces the maintenance time and cost. A remote fault database is established based on historical experiences and experts' knowledge. Various potential fault characteristics and sources are stored in this database as predefined data. Sensors are installed at key locations from different levels to collect real-time signals. Case-/rule-based reasoning are normally used in this fault matching process. After the fault is determined, corresponding methods of maintenances/repairs will be selected accordingly. If the matching is unsuccessful, experts in remote side will solve the problem and the solution will be saved into the remote database.

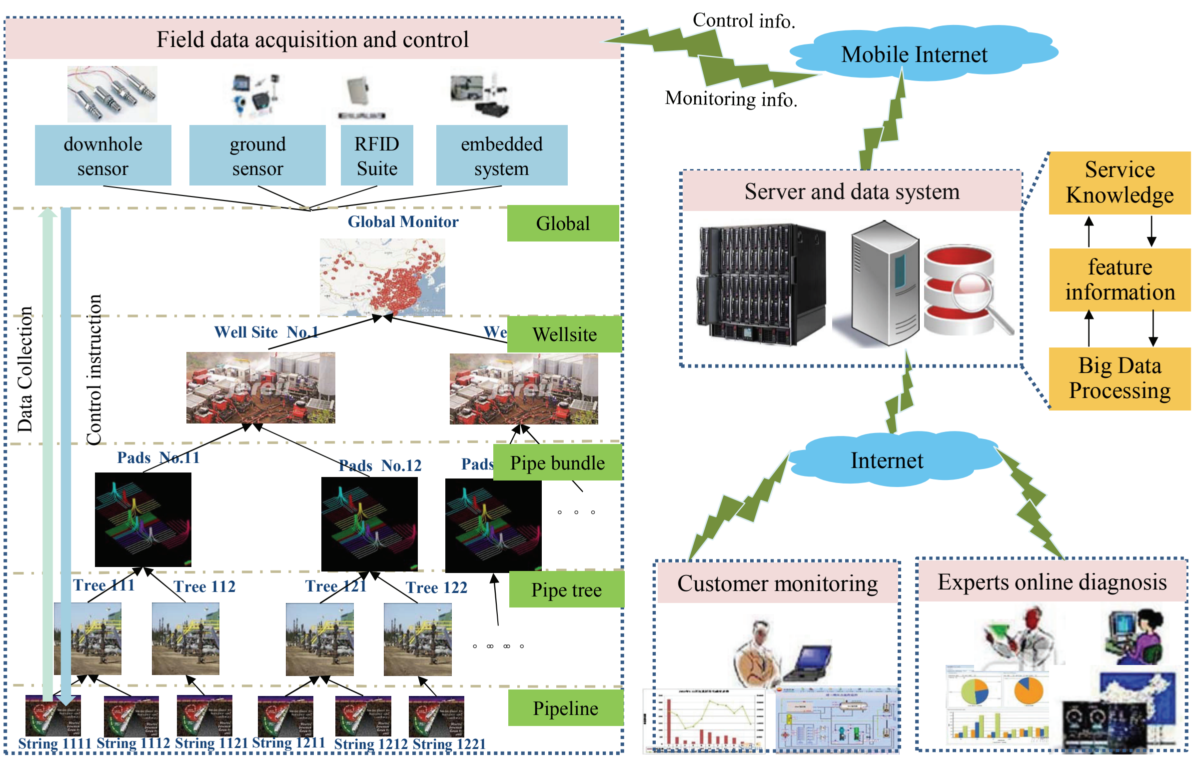

Figure 5. Running methodology of om-iPSS

C. Performance Management

Performance Management is to enable the providers to generate accurate reports to analyze the efficiency and effectiveness of their operation. The established om-iPSS running framework will help the operators to dynamically evaluate equipment health in different level and to make decision on types of inspection and maintenance program for specific stretch any time they desire. The Performance Management is confronted with a wide range of challenges that include quality improvement, reduced lead times, set up time and cost reductions, capacity expansion, managing complex technology and innovation, improving the reliability of systems, and related environmental issues.

As shown in Figure 5, "Field data acquisition and control" is a technical system that used to capture information related to location, process or group of functions. It shall be used to structure or represent different level of relationship, between organizational set-up, process and maintenance functions. "Server and data system" is connected to "Field data acquisition and control" by a boundary of Mobile Internet. The boundary is termed as a grouping of embedded and interconnected equipment which provides one main function for delivering bi-directional control and monitoring information from a maintenance perspective. "Server and data system" is master which is a uniquely identifiable physical signals, asset, upon which all notifications and work order can be carried out and recorded. By data classification and characteristic, big data analysis is used to enable equipment performance analysis. Using the Server and data system, oil mining equipment can be supplemented with technical characteristics, which provide further information on the equipment, including its technical and operational parameters. The customer can define characteristics freely and assign any number of them to the classes. The characteristics and their values can be inherited over several class levels in the case of hierarchically structured classes. The failure analysis can be done by expert online diagnosis since the information used is standardized at user interface.

D. Self-adaptive peer production

Scheduling is used after necessary planning has been conducted. Scheduling process involve mining activities to check availability of resources to perform the function. It operates a number of complexes operations, most of which are in the remote locations. The management and supervision of operational activities involves a flow of data, which can be most easily managed when consistent, meaningful information is readily available to all parties. This depends on the ready access to all information to design, construction, manufacturer, spare parts, skilled manpower resources and operating or maintenance histories. It is also to provide operations with a feedback mechanism to track their progress towards best practice.

Self-adaptive peer production is a process from curating and embedding tracking data to adjusting production. To achieve quick response to the dynamic envirnment, the production process state alongside the om-iPSS should be dynamic scheduled. The initial oil mining outsourcer allocates its mining tasks to the optimal service providers through a social intelligence based self-organized multiple outsourcing and subcontracts, which generates a mining-centered community. For a certain oil mining order, a comprehensive manufacturing service order monitoring network is shaped to realize the closed-loop management and control of the whole production and logistics process states. At its core, om-iPSS connects to a data warehouse then collects information from each other's operations software. As shown in Figure 5, though a dashboard-like interface, om-iPSS can display the data collected and organized across all these applications and allows it to be drilled into for greater insights into business activities and trends. It aims to realize the intelligent perception and connection into the internet of various physical manufacturing resources and abilities. Any enterprise expertise and customer within om-iPSS can therefore create a personalized information dashboard, which "democratizes" intelligence and embeds relevant data deep within the organization. Such information maps highlight particularly strong knowledge relationships within the community and may provide clues for new designs that optimize intelligence.

A sense of "added value" in products is becoming increasingly important to consumers because of the current economic climate and growing environmental consciousness. In other words, designed services should be evaluated from the viewpoints both of customer satisfaction and costs. Cost evaluation methods in service engineering such as ABC (Activity-Based Costing) have been intensively studied by many scholars. For concise reason, this section will not be discussed here.

V. CHALLENGES

Om-iPSS is a cross-disciplinary research and application field with theoretical underpinnings including both computational and service sciences.

A. Representing service-oriented production information and knowledge

Service-oriented production information and knowledge provide a basis for inferring, planning, and coordinating manufacturing activities. The characterization of complex structure and relations are typically represented via nodes and ties in om-iPSS networks, for which the key representational issue is the development of network models whose properties reflect the coupling reality. Network models must represent aspects of this reality in an interaction context, including oil miners' capabilities, resources, goals, and intentions. The Semantic Web and Ontology are promising in providing the tools and formalism for such requirements. This challenge is the foundation toward intelligence of om-iPSS.

B. System modeling with complex network theory

om-iPSS represented by a dynamic system is considered as an alternative possible realization of the target oil mining. To investigate system static characteristics and dynamic phenomena, analytic techniques from quantitative and computational sciences play a critical role. Within network analysis, traditional approaches have focused on static networks for small groups. As the technologies move forward, one major challenge for om-iPSS network analysis is to design methods and tools for modeling and analyzing large-scale and dynamic networks. Complex Network Theory might be the most promising approach. Of course, modeling with complex network theory doesn't exclude exact descriptions of om-iPSS systems. Actually, approximation with high accuracy is still the desired goal for many applications when it's achievable.

C. *Agent-based behavior simulation*

The last challenge is the modeling of operation behavior at both the individual and collective levels in the actual production and analysis and prediction techniques for om-iPSS. It is of interest to investigate how behavior and influencing factors change in om-iPSS environments by agent-based operation behavior modeling, which includes representing interaction context, modeling individual and differences, and how interaction norms and behavior emerge from micro-level interactions. Recent studies have started to explore the synergy for a better understanding of individual cognition and how to integrate cognitive and service sciences into cloud computing technologies. This may provide a guidance and foundation for implementation of om-iPSS.

VI. CONCLUSIONS

Oil sands mining are the nervous system of oil industry, as this transfers crude oil from down hole sources to refined products. Therefore, the efficient operations of these systems determine the effectiveness of the entire business. However, inspecting through specific inspection methodology cannot detect problems for the entire life cycle as inspection is designed to detect specific problems only. Thus, this study presented a novel industrial product service system for oil sands mining, which determines the problems associated with each life cycle phase with the involvement of the IT support. This leads to a cost-effective product strategy for the customers.

Om-iPSS is a new Internet-powered intelligent manufacturing landscape. It extends the crowdsourcing idea that "realizing distributed intelligent production through network" into oil mining area. Self-organizing peer production is the motive force and network effects are the new global market share. As the traditional computing is fundamentally unable to adapt to new production conditions, the novel service-oriented intelligent computing technologies are proposed as embedding knowledge in the om-iPSS for the whole life cycle of production process including designing, process planning, manufacturing, and maintenance. However, this isn't to suggest that om-iPSS will entirely displace current methods of intelligence manufacturing. But it should emerge as a strong complement.

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