Integrated Modeling Approach iServMod for Modeling, Analysis and Execution of collaborative Service Processes in Service Chains

Maik Herfurth
Global Information Technology
Hilti Befestigungstechnik AG
Buchs SG, Switzerland
email: maik.herfurth@hilti.com

Thomas Schuster
Faculty for Economy and Law
Pforzheim University of Applied Sciences
Pforzheim, Germany
email: thomas.schuster@hs-pforzheim.de

***Abstract* – Increasing market competition between service providers leads to further differentiation, currently often driven by offering so-called hybrid services. Hybrid services are typically implemented between several service providers as service chain. Hence, within service chains the effectiveness of collaborative, cross-company service processes constitute a major competitive factor. While basic service processes are typically company internal, service chains include cross-company administration, especially for service e-procurement. Hence, the collaborative service chains also require domain specific information about procurement and have to support information systems engineering. In turn, information systems have to support service e-procurement and operations in an integrated fashion. To improve the transition from planning to implementation of collaborative service processes with incorporated e-procurement, we suggest an integrated and formalized modeling approach. Our modeling approach will be practically demonstrated by case studies taken from the domain of industrial service procurement.**

Keywords – Service processes; service e-procurement; hybrid services; integrated modeling approach; modeling language; business process analysis

I. INTRODUCTION

Current surveys highlight that services increasingly create value offerings to customers and thus constitute an integral element of many products [1], this includes industrial services as one example of hybrid services. Industrial services make a significant share of companies total spending and ensure required operational levels and availability of systems and facilities. As a consequence, industrial service e-procurement is gaining importance and an integrated perspective of goods and services is required [2][3]. An example of service chains in this domain are industrial maintenance services. They are typically delivered through third-party service providers to grant availability and reliability of industrial facilities and infrastructures. For the procurement of these industrial services, several service providers and service consumers have to interact in industrial service chains [4].

In multilateral service chains where capital goods producers, goods and service requesters, as well as specialized service providers interact to produce, operate and administrate hybrid services. These cross company value added chains with flows of goods, cash and information are called *service chains* [5]. Hence, the ability to integrate and share products and services offerings of external business partners turns out to be a major competitive factor. In consequence, service suppliers take focus on supporting customer’s processes or even offering to provide larger parts of value creation processes. Service suppliers and service requesters are collaborating in industrial service chains. In these service chains, the production of services is in focus.

Since service requesters request different service types from different service suppliers, new ways of flexible collaborations are emerging. In this case service e-procurement constitutes an important segment of e-business activities. It compasses extensive use of *Information and Communication Technology* (*ICT*) to improve productivity and business processes. Electronic processes support business interactions reducing interfaces, process and throughput times and support improved harmonization of meta data, activities, procedures and integration of resources. E-business standards can help to support a shared process understanding and increase process transparency amongst business partners by harmonization and structuring of exchanged business data. In this way, e-business standards facilitate enhanced interoperability.

Electronic service processes of service chains are in focus throughout planning (modeling level) and operation (execution level). Nevertheless, there is still a lack for a precise modeling, analysis and benchmarking of these service processes. The paper is focusing on the development of an integrated analysis and modeling service processes in service chains. We suggest a formalized modeling method for collaborative business processes in service chains for further improvement. Our focus within that is the service e-procurement. The overall research approach is based and evaluated on case studies of a research and standardization project [6]. The remainder of this article is structured as follows: In section 2 the challenges of service e-procurement are outlined and the approach of iServMod is motivated. In section 3, the modeling approach of iServMod is presented while in section 4, the modeling of service objects, in section 5, the modeling of eSN and in section 6, the modeling of hSN are described in detail. After the application of iServMod (section 7), conclusion and outlook are drawn in section 8.

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II. Challenges and Motivation

Service chain collaborations achieve economies of scale, economies of scope and lower transaction costs. These collaborations are confronted with several challenges: The missing harmonization, integration and standardization of cross-company service processes. Therefore, the creation of new collaborations suffers from low quality of business interactions caused by integration and transaction costs, manual exception handling, offline communication (media breaks) and long procurement lead times; also resulting in less transparency and low quality of processes and data. The aforementioned shortcomings result from missing standards in document exchange and lack of information harmonization. Also, in the past service processes for administrative order processing in service chains did not draw much attention. However, especially these processes require many resources and incorporate long process and throughput times.

Inefficiencies result from internal and especially cross-company handling und coordination of transactions and non-harmonized and non-integrated electronic service processes. Service processes must support procedural rules and service logic of required interactions and communication between service suppliers and requesters [2]. Industrial service e-procurement is still source of high cost because underlying business processes are error prone. Errors and failures occur foremost through the absence of coherent e-business standards and reference frameworks offering meta models of processes, data objects and interaction patterns taking into account the service logic.

A. *Research Objectives*

Within this paper, we follow paradigms defined in design science. Thus, knowledge can be gained by creation and evaluation of artifacts in the form of models, methods and systems. In contrast to empirical research, the goal is not necessarily to evaluate the validity of research results with respect to their truth, but to the usefulness of the built artifacts as a tool to solve certain problems [7].

In this spirit, we will impose requirements driven by analysis of service and service e-procurement literature, interviews with domain experts as wells as hypotheses. The requirements analysis will disclose the decisions for the design concept of our planning approach. In contrast to an approach driven by theory, the basis for the design not necessarily has to be formulated as hypothesizes. Hence, the planning method will be constructed, implemented and tested in a real environment.

The paper proposes a model-based approach for the following reasons: information and knowledge has to be captured, before it can be part of sound analysis and utilization. Informal, semi-formal as well as formal models offer an abstract possibility to represent information and knowledge. Furthermore, graphical representations such as class diagrams, data-flow diagrams, state-transition diagrams or Petri nets ease understanding between stakeholders both for the expert and the non-expert. Overall this facilitates the communication between persons of different domains. In addition, formal languages allow to describe a certain phenomenon uniquely and precisely, but with a high level of abstraction of reality. They can be easily evaluated and verified or be used to automate certain tasks. The goal of this article is the definition of a modeling method which improves the quality of service chain definition by a domain-specific modeling approach, linked collaborative, cross-company service processes, hierarchical modeling structures, and precise modeling of processes and data.

B. *Planning and modeling requirements*

Due to these challenges, the modeling of service processes seeks for an adequate and precise integrated modeling approach as well as a precise system design for information systems. So far no adequate modeling approach based on a modeling language focusing the domain specific context of service e-procurement is existing. The modeling approach for system design should be based on a formal modeling language to enable the following advantages [8]:

- *adequate concept* for representation for domain specific description of data flow and control flow
- *formal semantics* of workflow processes due to a formalized syntax
- *uniqueness of syntax* and graphical descriptions for an easy understanding
- *expressiveness* for a precise system modeling
- *mathematical foundation* for evaluation and sound proof of system design
- *analysis of information systems* for properties like deadlocks, performance or the correctness of information systems (regarding requirements)
- *interoperability and vendor independence* of the modeling language, to support different modeling and analysis tools
- consideration of *static and dynamic elements* in business processes to describe the control flow and data flow.

III. State of the Art

Scientific literature reveals several approaches for service procurement with different focus and different granularity. *FlexNet Architect* [20] offers reusable modules for the scenario-based modeling of hybrid value creation. For planning and modeling of hybrid value creation networks, the cooperation definition, actors, areas and information flows can be modeled. The *HyproDesign* [21] modeling language was developed for modeling customer specific configurations and calculations of hybrid bundles of services and is based on a meta model to describe variants and configurations. Single modules are described as semantic models via *Entity Relationship diagrams* [22]. Winkelmann and Luczak [23] propose a Petri net based approach for the cooperative supply of industrial services by using *colored Petri nets* (*CPN*) [24].

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Becker and Neumann [25] define central components like processes and activities, technical objects, contacts and service offers based on data models for the order transaction of technical services. Che et al. [26] are using *XML nets* [11] for modeling, execution and monitoring of cross-company business processes. Mevius and Pibernik [27] propose XML nets for the support of business processes for the *Supply Chain Process Management* (*SCPM*). Every approach considers certain aspects of the description of services and service processes. But none of these approaches represents a comprehensive model for the description of service objects and service processes for industrial services based on a formalized approach. For modeling collaborative service processes and service objects in service transactions of service e-procurement, no such domain-specific approach considering the characteristics of service processes for service e-procurement is existing yet.

IV. Integrated Modeling Approach for Service Modeling *iServMod*

To meet the challenges and requirements described before, an integrated modeling approach based on a formal modeling language considering the domain specific context of service procurement will lead to the following advantages:

- *increased transparency in service chains*: service processes lack transparency due to individual internal service processes of service providers and service requesters.
- *precise modeling of collaborative service processes and data flow*: the precise modeling of service processes and service objects serves as a basis for high quality documentation and analysis. Internal service processes can be modeled separately and put together in service process models with an adequate modeling approach support.
- *analysis of service processes*: application of analysis methods for the quantitative and qualitative evaluation of service process models serve as a basis for benchmarking.
- *integration of domain specific context*: integration of service e-procurement context for its integration into information systems.
- *support of modeling and execution layers*: the modeling and the execution of service processes rounds up the comprehensive analysis of service process models.

Such a modeling approach results into the improvement of the efficiency (performance) and productivity of the service processes due to the reduction of process costs, reduction of process times, reduction of process throughput time, the improvement of process quantity, improvement of process transparency and increase of process flexibility. The integrated modeling approach *integrated service modeling* (*iServMod*) is based on Petri nets [9]. A Petri net is a formal mathematical modeling language for the description of distributed systems. A Petri net is a directed bipartite graph, in which the nodes represent transitions and places. The directed arcs describe which places are pre- and/or post-conditions for which transitions. With Petri nets, major network structures like sequence, iteration, alternative, concurrency, synchronization and contact can be modeled and dynamic properties like liveness, reachability, boundness and soundness can be analyzed [28]. High level Petri nets fulfill these requirements and support an integrated modeling of service processes and service objects.

A. Modeling Concepts

Based on *modeling concepts*, service processes and corresponding service objects can gradually be modeled in a top-down approach in detail or on a higher abstraction level. Service processes can stepwise be transformed into different formalization stages and their hierarchical scaling and modularization. For the modeling of different formalized service processes, the *screen model* [10] serves as a modeling concept for Petri nets. The modeling concept support four different formalized Petri nets modeling language types, starting from informal modeling languages (Petri nets) up to programming modeling language types for an automated execution (XML nets [11]). The modeling concept describes the successive transformation of these modeling language types of Petri nets. The hierarchical and modular modeling of service processes is supported by the *layer model* [12]. On a higher abstract modeling level, process phases are choreographed. On a detailed modeling level, complex electronic processes based on web services are orchestrated.

B. Petri Net based Modeling of Service Processes

Petri nets are extended by syntactical extensions. Therefore, the semantic of Petri nets and its characteristics aren't changed. The extensions serve as a basis for a detailed and precise modeling of service processes (design time) in order to integrate service processes on the execution level (run time). In the first step, the modeling of *service objects* as static components of data schemas is presented. Service nets as dynamic components of business processes are developed: *single Service nets* (*eSN*) based on place/transition nets are defined. *High level service nets* (*hSN*) based on XML nets in a second step are developed. With these Petri nets types, the screen model is supported.

V. Modeling of Service Objects

Service objects describe static object-oriented components in service processes. Service object are identified data objects which describe central service master data and transaction data. These data are service requesters and service provider data, materials, service and business documents. Service objects are input and output objects of service processes. Service objects are economically relevant data objects which are executed in electronic service processes as workflows. Service objects are relevant data objects like a service specification, a service order, a service invoice or another service-relevant data object for service transactions of service e-procurement.

For the graphical modeling representation, service objects are modeled with the XML schema model (XSM) [11] as modeling constructs in XML nets. XSM serves as a formal object description method to describe complex object structures in conjunction with organizational processes. As an example, the service object *industrial service description* is shown (Fig. 1).

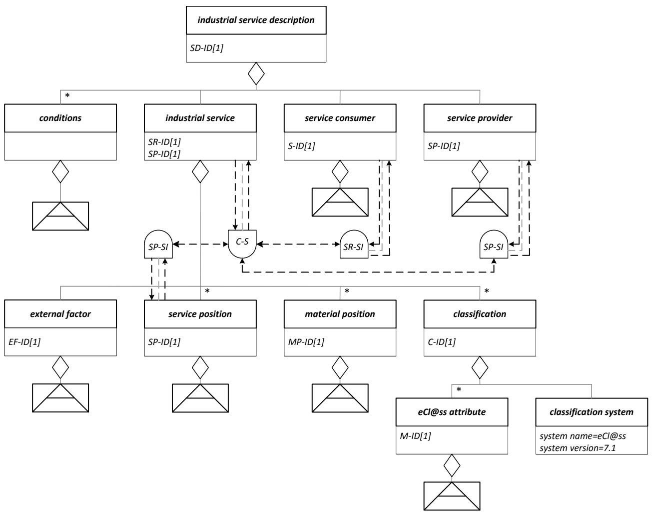

Figure 1. Service object *industrial service description*

XML schema diagrams are used to describe service objects. Data structures in XML nets are determined by Petri nets places. Places combine structured service objects with a common schema (typification of places). The modeling constructs of XML schema models are element types represented by UML classes and dependencies represented by association types.

VI. SINGLE SERVICE NETS ESN

For the modeling of *eSN*, we utilize places/transition nets (P/T nets) to support initial modeling phases. Places and tokens of these nets represent the current status of a service chain. Domain specific process interface place types and process transition types are defined to standardize modeling. Internal (private) service processes are modeling by *pools*. The interface place types *service object places* (*SO*), *service interface places* (*SS*) and *service document places* (*SD*) are defined. *SO* places are containers for general service objects.

SS places are internal and cross-company interfaces for the data flow. Static interface places between service processes and dynamic interface places for capsulated interface processes are defined. *SD* places serve as containers for service document types. For transition concepts, *service process phases* (*SP*) are defined to reflect the specific process phases in service procurement. *Service process modules* (*SM*) represent service processes of a collaboration participant (service provider or service requester). *SP* and *SM* represent both a black box for further detailed modeled service processes. A service process phase consists out of service process modules. Service process phases and modules represent and apply hierarchical modeling concepts to support the layer model. As an example, the singe collaborative service process between a service provider and a service requester is shown in Fig. 2.

VII. HIGH LEVEL SERVICE NETS

The use of P/T net concepts accompanies a couple disadvantages: the semantic correctness cannot be checked, domain specific modeling constructs are not supported, communication and information concepts are not designed, the structured hierarchical modeling is not supported and tokens cannot be specified individually. Thus we introduce modeling extensions of *eSN* with transfer to higher level service nets on the basis of XML nets with individual tokens.

High level Service nets (*hSN*) are based on XML. Thus operational sequences and the document flow are based on XML and all tokens of are represented by complex structured XML objects. All activities correspond to operations on XML documents. *hSN* are characterized by domain specific extensions, and individual tokens. Furthermore, within *hSN* the phases of service chains are standardized. Thus, e*lectronic service processes* and their data flow can be precisely modeled, analyzed, simulated, executed and maintained.

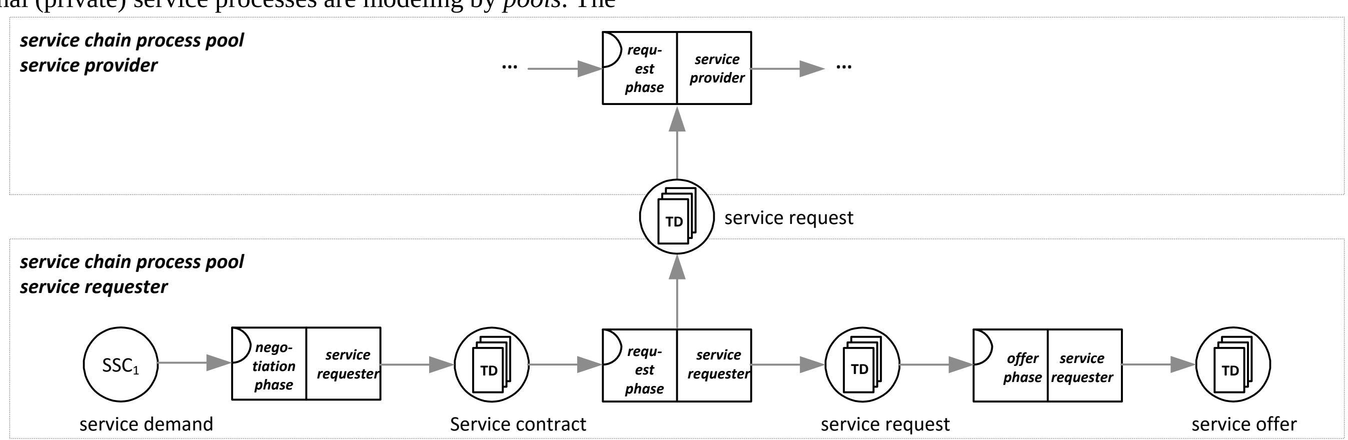

Figure 2. Single collaborative service process with pools of service provider and service requester

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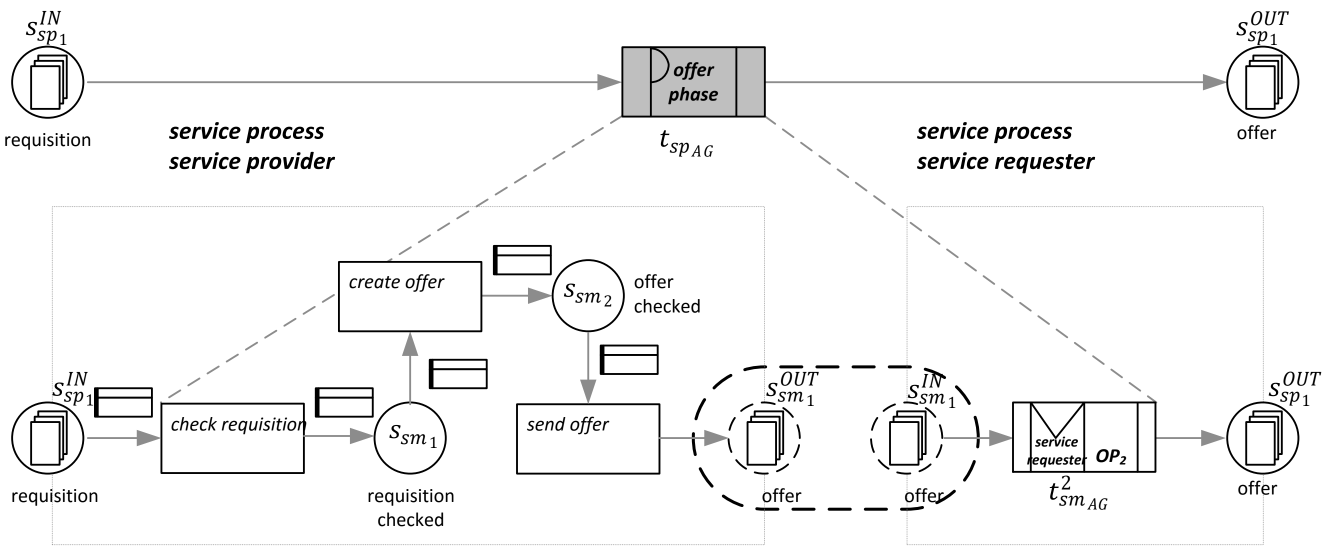

Figure 3. Modularization of a service process phase by service process modules

For the process interface place types, places are typified based on the domain specific context. *Service process phases (SP)* are represented by coarsened transitions with capsulated service processes based on service process modules. Service process modules are also coarsened transitions and contain capsulated service processes of one process participant (internal service process). Service process modules contain a service process which fulfills the requirements of a Workflow net [13].

A service process module is defined by an internal structure and communicates with other modules based on process interface places. *Service process modules (SM)* describe unidirectional and bidirectional interaction and communication patterns. Service process phases and service process modules contains typified input and output places *SO*, *SS* and *SD*. Service process phases are defined with specific typified places in dependence on process patterns. Service process phases and service process modules are syntactically compatible.

The service process phase offer ($t_{sp_{AG}}$) is modularized by two service process modules (Fig. 3). The service process consists of the service process hSN'_{sm_1} of the service process module $t^1_{sm_{AG}}$ and hSN'_{sm_2} of the service process module $t^2_{sm_{AG}}$. hSN'_{sm_1} of the service provider is modeled as an XML net. The representation of XML filter schemes FS_i, transition inscriptions TI_i and place type definition ST_i are not modeled. The service process of the service requester is represented by the service process module $t^2_{sm_{AG}}$. The place $s^{IN_1}_{sp_1}$ and the place $s^{OUT_1}_{sp_1}$ are the in- and output of hSN. The input place $s^{IN_1}_{sm_1}$ ($s^{IN_1}_{sp_1}$) and the output place $s^{OUT_1}_{sm_1}$ as the input place $s^{IN_1}_{sm_2}$ and the output place $s^{OUT_1}_{sm_1}$ ($s^{OUT_1}_{sp_2}$) are module interface places of the service process modules. Thus a high level Service net *hSN* is defined as follows:

A Service net is defined as a tuple $hSN = (S, SSO, SSI, SSD, T, TSP, TSM, F, \Phi, I_S, I_T, I_F, I_{SSO}, I_{SSI}, I_{SSD}, M_0)$, where

1. $XN = (S, T, F, \Phi, I_S, I_T, I_F, M_0)$ is an XML net.
2. $\Phi = (\mathrm{E}, \mathrm{FKT}, \mathrm{PRE})$ is a structure consisting of a non-empty and finite individual set E of Φ, a set of formula and term functions FKT defined on E, and a set of predicates PRE defined on E.
3. The set of places is structured in the sets process object places SPO and service object specific places SPS. The set of SPS is further structured in the sets of service object places SSO, service interface places SSI and service document places SSD.
4. The set of transitions is structured in the sets of process activities TPA and service process activities TPS. The set of TPS contains of service process phases TSP and service process modules TSM. The set of TPS is defined as a real set of transitions T: $TPS \subseteq T$.
5. I_{SSO} is the function that assigns a valid XML schema as a place typification to each place $s_{so} \in SSO$.
6. I_{SSI} is the function that assigns a valid XML schema as a place typification to each place $s_{si_s} \in SSI$.
7. I_{SSI} is the function that assigns a valid XML schema of a service documents type *j* as a place typification to each place $s_{sd_j} \in SSD$.
8. I_T is the function that assigns a predicate logical expression as inscription to each transition on a given structure Φ and the set of variables which are contained on all adjacent arcs.
9. I_F is the function that assigns a valid XSLT expression to each arc which is conform to the adjacent XML scheme.

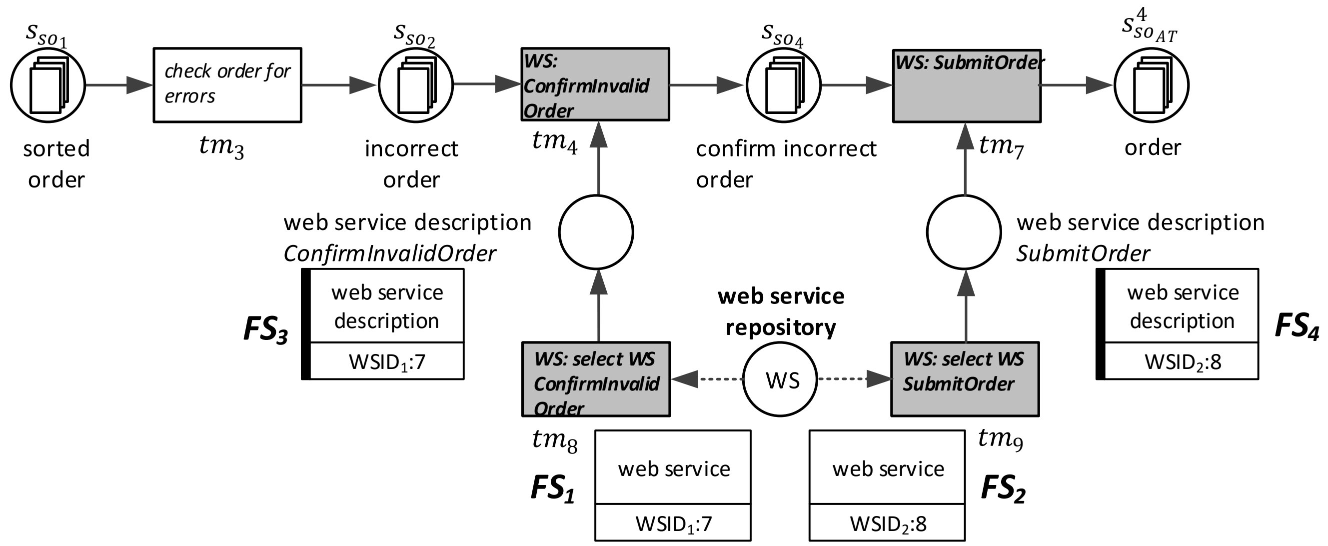

Figure 4. Web Service net with web service selection

A. Modeling of distributed Service Processes based on SOA

Service processes can be modeled as dynamic interface processes and be executed by web services in *service oriented architectures* (*SOA*). *iServMod* supports the modeling and analysis of distributed service processes based on web services by *Web Service nets* (*WSN*) [14]. A web service is considered as an implementation of a local service process (interface process). A distributed service process can be realized by the composition of web services. Input and output messages represent the data flow in Web Service nets. Web Service nets also support the composition concepts like the orchestration and choreography. The example service process *validation of incorrect orders* is models as an abstract Web Service net with web service selection (Fig. 4).

B. Transformation and Execution of Web Service Nets

Based on the precise modeling of all aspects of service processes with Web Service nets, *Web Service Business Process Execution Language* (*WS-BPEL*) elements can be derived to use standardized web service technologies like interface description (*WSDL*), protocols (*SOAP*) or service discovery (*UDDI*). Web service process models [15] can be modeled and the transformation of Web Service nets into executable WS-BPEL code is based on control flow and data flow structures. Specific structures and elements can be identified and transformed into equivalent WS-BPEL structures. A detailed transformation of Web Service net structures into WS-BPEL code with a transformation algorithm is defined in [16].

VIII. APPLICATION OF iSERVMOD IN USE CASES

The integrated modeling approach *integrated Service Modeling (iServMod)* serves as an adequate method for a precise modeling and analysis of service processes. The advantages of *iServMod* increase the value of business process simulation and business process benchmarking. The simulation of service processes based on key performance indicators reveals gaps and weaknesses. The execution of a process benchmarking identifies differences of relevant factors like throughput times, resource assignments or cost items. The causes of performance gaps can be analyzed. For the modeling and simulation of service process models, the software tool *Horus* [18] was enhanced by the new modeling extensions of Service nets and used for a software based simulation. As business process simulation method, a discrete event driven business process oriented simulation was used [19]. The strengths of the independent simulative analysis are the possibility of a "*playground*" by simulating different process alternatives. Evaluation of simulation results can shed light on correlations of system parameters at build time and can be used to develop action strategies [1]. Unlike analytical procedures, the simulation can be used for the analysis of large systems. Based on benchmarks, performance gaps can be quantified. Redundant service processes and non-value creating activities as well as automation potentials for service processes can be identified and the error data is reduced. Also the cost-effectiveness of service processes can be ensured.

The integrated modeling approach *iServMod* has been successfully applied in a research projects in the domain of service procurement [2]. The service process models of 18 use cases between six service suppliers and four service requesters were analyzed, modeled, simulated and benchmarked [1][6][17]. Service process models were modeled with high level Service nets. The modeling of Service nets was based on a reference process model [2] to structure and align the individual service processes. *iServMod* supported the precise modeling of service processes and service objects in a syntactical correct and semantic formal way. The data flow could be modeled based on XML. Service processes could be model in a hierarchical modeling approach based on different abstraction levels to support modeling user groups with different modeling experiences. Service processes could be modeled top down from high level process description to detailed service processes as workflows using web services and representing and supporting a further implementation in information systems. Service process phases and service process modules allow for reusability of pre-defined concepts by assuring the syntactical and semantic compatibility in service process models. The evaluated uses cases were compared pairwise for benchmarking by applying the presented procedure model.

IX. CONCLUSION AND OUTLOOK

We presented the integrated modeling approach *iServMod* based on formalized modeling techniques. *iServMod* supports integrated modeling of service processes and service objects. Additionally, *iServMod* offers an adequate modeling approach for the precise analysis and implementation of service processes. *iServMod* is focusing on collaborative service processes which are modeled independently by different companies and their domain experts (modelers). It furthermore supports the domain specific requirements of service e-procurement in service chains.

The presented modeling concepts enact different formalization levels, starting from a semi-formal description of service process models up to highly formalized and executable service process models. This includes a hierarchical order of service processes typically modeled ion a top down approach utilizing service process phases. The modeling approach is concluded by integrated description of web service calls to implement sound information systems at execution level. The syntactic domain specific extensions both of service object specific process interface place types and process transition types enable a precise hierarchical modeling of process participants, modular service processes, e-procurement service phases, pre-defined process patterns, interfaces and service data objects.

While *eSN* serve as an initial modeling approach and further analysis based on Petri nets, *hSN* enable an integrated modeling of service processes and service objects for the design of information systems. The integrated modeling and design approach was evaluated with real-life case studies [2]. The service process models have been modeled and analyzed and the developed extension of the software tool *Horus* supports the overall modeling of collaborative service chains.

As next steps, we foresee the evaluation of *iServMod* by a survey of domain specific users to determine. We also strive to further evaluate the performance, quality and efficiency of this approach together with several leading companies in the domain of industrial services. Furthermore, the adoption and application of *iServMod* in different domains and hence different types of service chains are planned.

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