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Management Summary

In this deliverable we present our work on different aspects of Service Networks (SNs) in two parts. In the first part we discuss SNs fundamentals, presenting a life cycle of SNs that breaks down the creation, implementation, enactment, monitoring and optimization of a network into five distinct phases. Each of these phases interacts with different aspects of the S-Cube research framework. In this deliverable we focus on the initial, modeling and simulation phase of the life-cycle. The second part of the deliverable focuses on the application of simulation techniques to two interrelated types of network analysis: value and performance analysis.

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List of acronyms

ABM	Agent-Based Modeling
ANT	Actor Network Theory
BPEL	Business Process Execution Language
BPM	Business Process Management
BPMN	Business Process Modeling Notation
bQoS	business Quality of Service
DES	Discrete Events Simulation
IS	Information Systems
KPI	Key Performance Indicator
KPO	Key Performance Objective
MSOAM	Service Lifecycle Process, Service-Oriented Modeling Framework, Mainstream SOA Methodology
QoS	Quality of Service
SaaS	Software as a Service
SBA	Service-Based Application
SD	System Dynamics
SLA	Service Level Agreement
SN	Service Network
SNA	Social Network Analysis
SNPA	Service Network Performance Analytics
SOA	Service Oriented Architecture
SOC	Service Oriented Computing
SOMA	Service-Oriented Modeling and Architecture
WSDL	Web Service Description Language

1 Introduction

The digital landscape is rapidly being transformed into a global, services-centric economy where economies of scale are realized through networked enterprises transacting and co-creating value through digital infrastructures with a global reach. The global digital economy is fuelled by new distributed computing technologies. Many of these technologies are provided through the Internet and enable cheap provisioning, scalability and seamless connection to anyone, everywhere. They are impacting the way in which we live our daily lives, conduct business and shape our societies.

The explosive growth of services economies, coupled with the evolution of powerful digital communication networks – which we tend to associate with the Internet – help transform service companies and their clients alike from regional businesses to globally integrated, value-creating *service networks* [1],[2].

Service networks are in essence open, complex and fluid, socioeconomic systems of organizations and processes that break away from classical hierarchies of knowledge and power, to accommodate the co-production of new knowledge and services through organic peer-to-peer interactions (cf. JRA-2.1.3). SOA is heralded as a natural candidate to develop and manage service networks as choreographed, event-driven software and human-operated services that collectively realize end-to-end processes.

Service networks embody end-to-end processes that are layered on services that providers offer and clients consume, and that may be connected at a global scale. Resources in service networks may include people, software systems, computing devices and infrastructures, organizations and shared information, such as business rules, regulations, measures and methods. Resources are connected internally and externally through value propositions [5]. In particular, a service network may be designed as a collection of end-to-end processes – such as when handling a customer order from purchase to payment – that are enacted with software service applications and human-operated services.

Figure 1 depicts a more detailed overview of the anatomy of a service network defining a stratified model comprised of five interrelated strata. In particular, the top-level stratum defines end-to-end processes connecting service provisions of (networked) service providers. In this case, an Original Equipment Manufacturer, Car Manufacturers, and, Car Dealers. In this way a service network can be partitioned into a set of discrete business services that completely process service client requests.

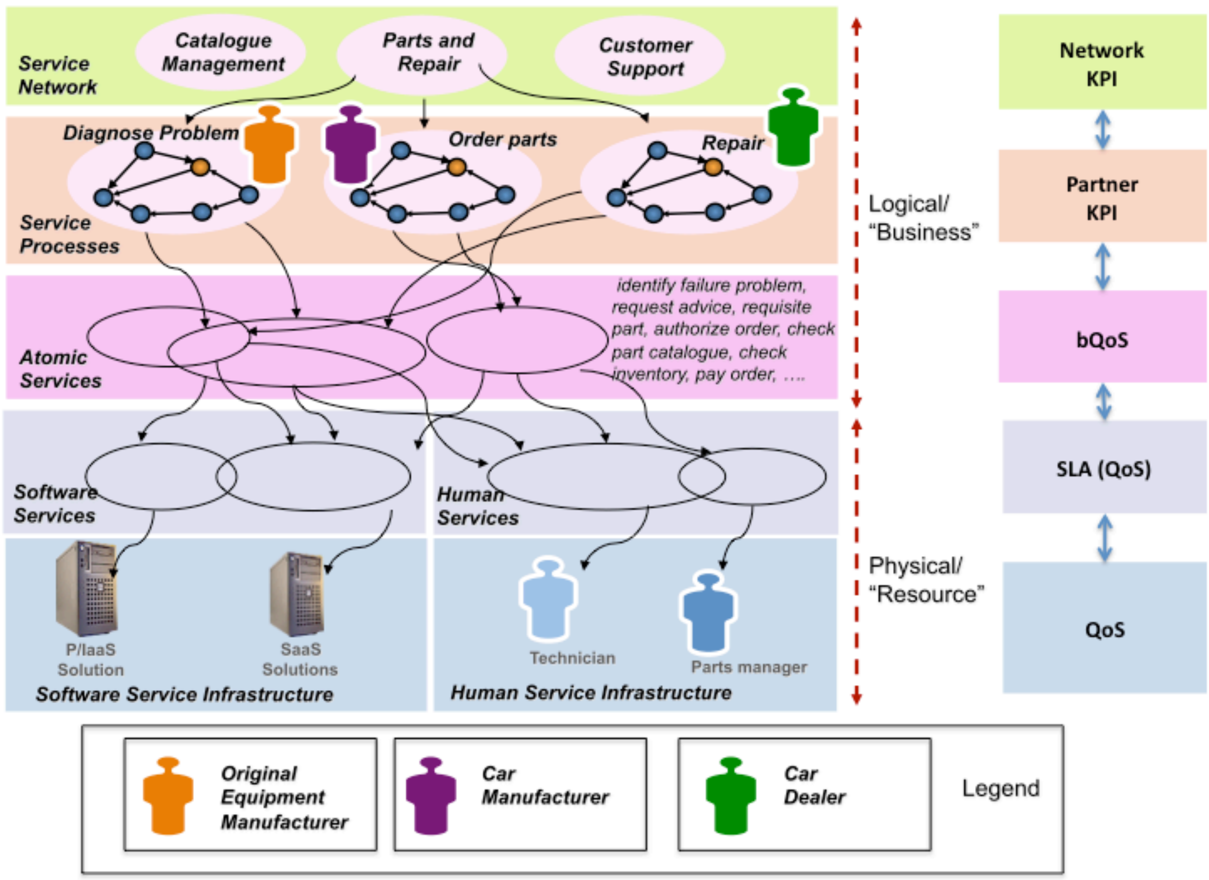

Figure 1 A Service Network for the Automotive Purchase Order Processing Scenario

Figure 1 is based on the car repair network case as described by Saimaresh et al. [3] and was incorporated into the Automotive Purchase Order Processing Scenario [4]. The figure shows how an end-to-end process is subdivided into *composite service-enabled business processes* – in short, *service processes* – that fall under the control of one single end-point, such as diagnosing the problem to be repaired (OEM), ordering part replacements (Car Manufacturer) and performing the repair (Car Dealer). The order process shown in Figure 1 is a composition of several atomic services (see corresponding stratum) such as investigating failure symptoms, identifying parts, ask advice from technicians, and ordering the appropriate (possibly upgraded) parts. Software and human service resources can be routinely mapped to atomic services, and can be selected, customized and combined into aggregated service applications using technologies such as BPEL4People[1]. Typically, the software services that are developed at this level are provided as Web services or "Software as a Service" (SaaS) solutions. Lastly, the software service may be deployed on a software service infrastructure stratum, which may for example be a distributed cloud (e.g., "Infrastructure as a Service") environment, providing the capabilities required for enabling the development, delivery, maintenance and provisioning of services as well as capabilities that monitor, manage, and maintain Quality of Service (QoS) characteristics such as security, performance, and availability.

[1] http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=bpel4people

The right hand side of Figure 1 shows for each stratum an associated value performance measurement, scaling the time horizon up from (milliseconds) at the level of software service resources to months or years at the level to the service network. The observed trend is to move to high-value service networks, where business process interactions and trends are examined by business process analysts closely to understand and predict more accurately client needs and application performance. This trend gives rise to new service analytics models and techniques that will help to pro-actively manage services and pinpoint areas for improvement. Such an end-to-end view enables to quickly isolate and troubleshoot the root cause of process bottlenecks, e.g. failure of an order due to the unavailability of just-in time production alternatives, potential performance problems, e.g., loss of goodwill, and tune proactively.

In the rest of this document we summarize the key contributions of this deliverable, before illustrating the connection with the rest of the S-Cube research framework. In order to provide the context for the works that follow, we also briefly discuss the changes to the workpackage (WP) description and clarify the novel focus of the work performed under its auspices. Following on, in Section 2 we discuss some fundamental notions for service networks in the form of a reference life cycle for them and the modeling tools we developed particularly for service networks. Section 3 discusses some of the applications of service modeling and simulation in estimating the generated value and the potential performance of service networks. The full papers for each of these works are contained in the Appendix. The deliverable concludes with Section 4, presenting future collaborations that we envision with the other WPs in S-Cube.

1.1 Contributions of this deliverable

In this deliverable we investigate different aspects of service networks (SNs). In particular, we present in two parts five articles and papers that have been either submitted to conferences/workshops and journals, or accepted for publication. In the first part we discuss service networks fundamentals, presenting a life cycle of SNs that breaks down the creation, implementation, enactment, monitoring and optimization of a network into five distinct phases (see Figure 2 in Section 2.1). Each of these phases has a particular way of approaching SNs and interacts with different aspects of the S-Cube research framework. For example, monitoring of SNs requires the use of a number of techniques developed by the workpackage Adaptation & Monitoring (WP-JRA-1.2). In addition however, it requires network-level monitoring capabilities that go beyond aggregating monitoring each service in the network individually and aggregating the results, and require a higher-level view of the interactions between the participants of the network. Given the scope and effort required in addressing all such issues, in this deliverable we focused on the modeling and simulation phase of the life cycle.

In the first part of this deliverable we address the modeling aspect. We elaborate our work on a notation for the modeling of SNs that builds forward on our work reported in deliverable JRA-2.1.2 and focuses on depicting the interactions between the partners of the network (paper 1, pp. 21 in Appendix A). As part of this effort, we also develop a mapping between business process models and service network models and we discuss how to transform high-level business processes into specific service network topologies. Furthermore, based on the SN modeling notation we introduced, we also develop a more refined modeling mechanism for SNs in the form of views on the SN (cf. [8]). In particular, we distinguish between offering-centric and global views; the former are focusing on the interactions of one participant of the network at a time, while the latter represent the totality of the information about the SN available a to business analyst. Both views are critical tools in modeling the characteristics and behavior of the network before we proceed to put it into place. Finally, we present the early results of a service network modeling approach that relies heavily on simulation techniques in order to consider different network configurations and resource allocations and their effect on the behavior of the network (paper 2, pp. 47 in Appendix A).

The second part of the deliverable focuses on the application of simulation techniques for two interrelated types of network analysis: value and performance analysis. We present simulation-based approaches on estimating the value generated both on a local level (that is, of one participant) and a global level (of the whole network) so that the network can be designed in a more efficient manner (cf.

paper 3 on page 57 in Appendix A). A hybrid approach to predict performance at the level of softare services as well as end-to-end processes in service networks is then presented in [9] (paper 4, pp. 64 in the same appendix) In addition, we use social network analysis techniques to model and simulate the performance of each participant, with the clear goal of increasing the manageability of SNs (cf. paper 5 on pp. 72).

1.2 Relation to the S-Cube Integration Framework

1.2.1 Relation to Other Work Packages and Deliverables

The work presented in this deliverable has a major role in the scope of JRA-2. Since it enables modeling and analysis of Service Networks, the modeling and analysis concepts will particularly impact the work done on the level of service compositions in WP-JRA-2.2, especially concerning the mapping of SNs to and their enactment in terms of coordinated service compositions.

Sitting on top of the S-Cube JRA stack, the presented research work in JRA 2.1 serves as the basic input for several WPs in the JRA and to the Integration Framework as a whole. Moreover, most of the research results are part of integration effort across all WPs in the JRAs, in particular:

- In terms of the life cycle of service networks, engineering principles for SBAs enacting service networks and the respective techniques and methodologies with JRA-1.1.
- Modeling techniques for enabling analysis and simulation of SNs and the corresponding analysis and optimization approaches (with JRA-1.1 and JRA-1.3).
- Additionally, modeling for SN monitoring and capturing the relationship to monitoring of business transactions, service compositions of the level of Service Composition and monitoring of Services (WP-JRA-1.1 and WP-JRA-1.2, as well as WP-JRA-2.2 and WP-JRA-2.3).

1.2.2 Relation to the S-Cube Research Challenges

The work presented in this deliverable will contribute to the S-Cube research challenge “Concepts, Languages and Mechanisms for Agile Service Networks” [[15]]. As such this deliverable is also related to work on the challenges in all other WPs in JRA-1 and JRA-2.

The way this work will affect the WPs Coordinated Service Compositions and Service Infrastructures is explicit and will inevitably influence the approaches for adaptation of services and service compositions (including identification of novel triggers for adaptation and fragmentation of processes), which are challenges identified for **WP-JRA-2.3 and WP-JRA-2.2**. The modeling and analysis techniques for service networks are only a first step towards addressing the challenge (in WP-**JRA-2.1**) of enacting business transaction in terms of SBAs.

Since Service Networks are one novel view on business processes and business transactions in terms of (business) criteria relevant for enterprises, the challenges all the WPs in **JRA-1** face will have to be addressed in the context of the work done in this deliverable. In particular, the life cycle of SBAs will incorporate the lifecycle of SNs and the mapping between the life cycles of SNs and business transactions as well as the mapping of the same life cycle to those of service compositions and services, for the purpose of SN enactment using SBAs. The work on SBA design principles will also investigate the influence of SN modeling, analysis and monitoring techniques on SBAs.

Due to the fact that SNs can be used to enable the evaluation of business relevant metrics and thus trigger changes on all layers of an SBA, considering the work presented in **JRA-1.2** (Adaptation and Monitoring Framework) is a must in order to ensure addressing the challenges in JRA-1.2 in an integrated manner. New adaptation techniques that take into account SN models will have to be developed and currently available adaptation techniques for service compositions will have to be revised to incorporate the adaptation techniques for SNs. The research done to address the challenges in **JRA-1.3** (Quality Assurance of SBAs) can use the concepts and techniques presented here as input towards extending the quality assurance model of SBAs and investigate further the effect of these approaches is on the SLAs on all functional layer of an SBA.

1.3 Changes to the WP description

The description of work in the context of JRA-2.1 has been trimmed down, streamlined and edited, replacing text passages which were out of scope (e.g., work on trust negotiation protocols and compliance which belongs to JRA-1.3, and work on compatibility of orchestrations which is investigated in JRA-2.2), outdated (paragraph that states that change cannot be dealt with using current process technologies), and/or superfluous with an updated description.

The updated description is more focused, up-to-date and better aligned with the S-Cube phased approach, placing more emphasis on three key challenges that will be tackled during the remainder of S-Cube:

1. modeling (reusable) business transactions,
2. formal (run- and design-time) analysis and simulation of service networks, and
3. integration of work on business transactions with that of service networks with realistic use cases.

A more detailed description of the changes in the WP description can be found in deliverable CD-Mgt-1.3.1 (November 2010). This deliverable, and the research work contained therein, is in line with the new description of the WP and focuses on the presenting useful techniques for modeling and simulating service networks.

2 Service Networks Fundamentals

2.1 SN Lifecycle

Over the last years, several analysis and design methodologies have emerged for engineering service-enabled applications. Prominent examples include: Service Lifecycle Process, Service-Oriented Modeling Framework, Mainstream SOA Methodology (MSOAM), and Service-Oriented Modeling and Architecture (SOMA). Unfortunately, however, none of the above methodologies were designed with service networks in mind, and embrace the closed-world assumption that applications have clear boundaries and will be executed in fully controlled, homogeneous, predictable and stable execution environments.

These methodologies thus cannot be expected to effectively cope with the increased levels of complexity and dynamicity of service networks that typically exhibit non-linear, non-deterministic and unpredictable behavior. In addition, and even more problematically, existing SOA development methodologies largely fall short in assisting application designers in evaluating the impact of design decisions on the performance at the level of service-enabled applications and the business processes they support. *Performance* of service networks refers to their ability to accomplish service specific objectives at the level of service resources, including human-operated and software services, and strategic business objectives at the level of the end-to-end processes that live within them.

A service-oriented design and development methodology for service networks should be based on an iterative and incremental process. In [6] we propose a methodology for engineering service networks that refines existing SOC methodologies, and comprises five main phases that may be traversed iteratively, catering for service network design centered on performance analytics. The phases, illustrated in Figure 2, are:

1. Modeling (including network analysis and design),
2. Implementation and testing,
3. Deployment and execution,

4. Analyzing and monitoring, and
5. Measuring and optimizing.

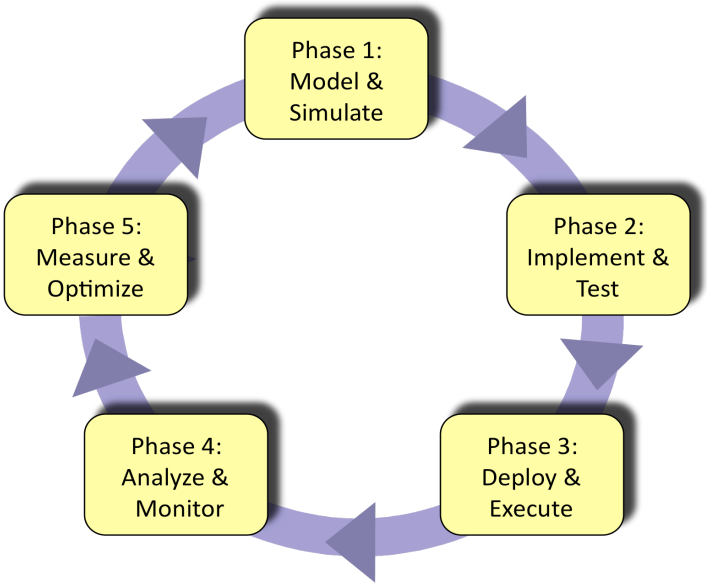

Figure 2 The Service Network Lifecycle

The first phase aims at producing a logical and physical design of the service network. The service designer starts with *conceptualizing* the network in terms of the network partners, the end-to-end processes that live within the network and the choreographed software/human services that implement them. The logical design typically entails abstract models of the process and service choreography rendered in conceptual notations such as the BPMN 2.0 Business Process Diagram, Collaboration Diagram and Choreography Diagram. Ideally, these models are calibrated to meet performance requirements for the end-to-end process in terms of Key Performance Indicators (KPIs), and, support service resources in terms of QoS. The second phase involves coding or identifying reusable service resources and choreographing them into end-to-end processes using the physical specifications, typically relying on the well-known standards from the WS-stack, such as WS-Policy, WSDL and BPEL. It also involves testing coded services and processes for functional correctness and completeness as well as for interoperability.

The service network deployment and execution phase continues enforcing the business model for service provisioning, addressing issues service metering, service rating and service billing. Once the provisioning model has been established, the service network may be deployed recursively, involving deployment of human-operated and software (Web) services by all partners in the service network. Execution includes the actual binding and run-time invocation of the deployed choreographed services. The next phase involves monitoring and analyzing the execution of the service network, resolving potential process and service anomalies including unforeseen interoperability conflicts. Lastly, progress of executing end-to-end processes in the service network are measured against performance metrics, such as KPIs, and optimized on an as-needed basis.

In [6] we introduce a lifecycle model approach of continuous invention that considers multiple realization scenarios for end-to-end processes and Web/Human services that take into account both technical and business performance concerns in service networks. Basically, we suggest to leverage conventional approaches with phase one (model & simulate) and five (measure & optimize) of the Service Network Lifecycle to effectively address performance analytics of service networks: design time and runtime.

Design time service analytics utilizes conceptualizations (i.e., the logical models) of service networks to verify their performance against agreed-upon service levels of partner-level and network-level processes. Runtime service analytics study event logs that are provided by service monitoring tools, and measure progress of end-to-end processes against performance metrics, and proactively pinpoint areas for process improvement and troubleshoot the root-cause of bottlenecks. Due to reasons of space and scope, only design-time performance analytics are considered in [6].

In particular, the main aim of this paper is to develop and partially validate an analytical model to guide and foster the logical design of service networks. The analytical model - supported by an appropriate tool - helps service engineers in predicting the impact of design decisions on performance of service networks. Relying on the presented analytical model, service architects may methodically assess the performance trade-off of different process configurations and alternate resource allocation schemes. The outcome of such predictive strategic planning exercises may not only be useful to ascertain acceptable performance of the network, but also be used as a baseline for business activity and business process monitoring tools and other monitoring platforms used within the network.

2.2 Modeling of Service Networks

Organizations, enterprises and human actors are necessarily woven alongside their business partners in service networks that ensure their well-being and allow them to perform their operations. Service network models provide representations of (existing or hypothetical) business relationships. In combination with business processes and service compositions, service network models facilitate the critical alignment of the business and IT perspectives for enterprises.

More specifically, a *service network model*, like the one shown in Figure 3, depicts the exchanges of services occurring in a service network, albeit without specifying the operational details of the business processes that realize those exchanges. Continuing our work reported in CD-JRA-2.1.2, in [7] we introduce a formal modeling notation for service networks that allows service network designers to specify:

1. the *participants* of the service network,
2. the *service requests* and *service offerings* they expose,
3. the *relationships* between the participants, and
4. the *dependencies* that denote how service offerings and requests satisfy and depend on each other.

The participants of a service network can be enterprises (and parts thereof, e.g., divisions) as well as humans. The services made available on the market by the participants are modelled as service offerings. The service requests of a participant express the latter's need for consuming particular services. Both service offerings and service requests are associated with service descriptions (e.g. USDL[2] documents) and may contain additional information, e.g. pricing schemes. The participants of a service network may be engaged in different relationships. In [7] we consider only some types of relationships among the participants, namely:

- *subordination* of one company or (sub-)organization to another,
- *affiliation* of a human actor to a company or organization, and
- *service providing*, which represent the satisfaction of service requests of some participants through the consumption of service offerings provided by others.

Service providing can be regulated by contractual agreements such as Service Level Agreements (SLAs), and may combine multiple service offerings and service requirements originating from different participants.

[2] http://www.internet-of-services.com/index.php?id=54

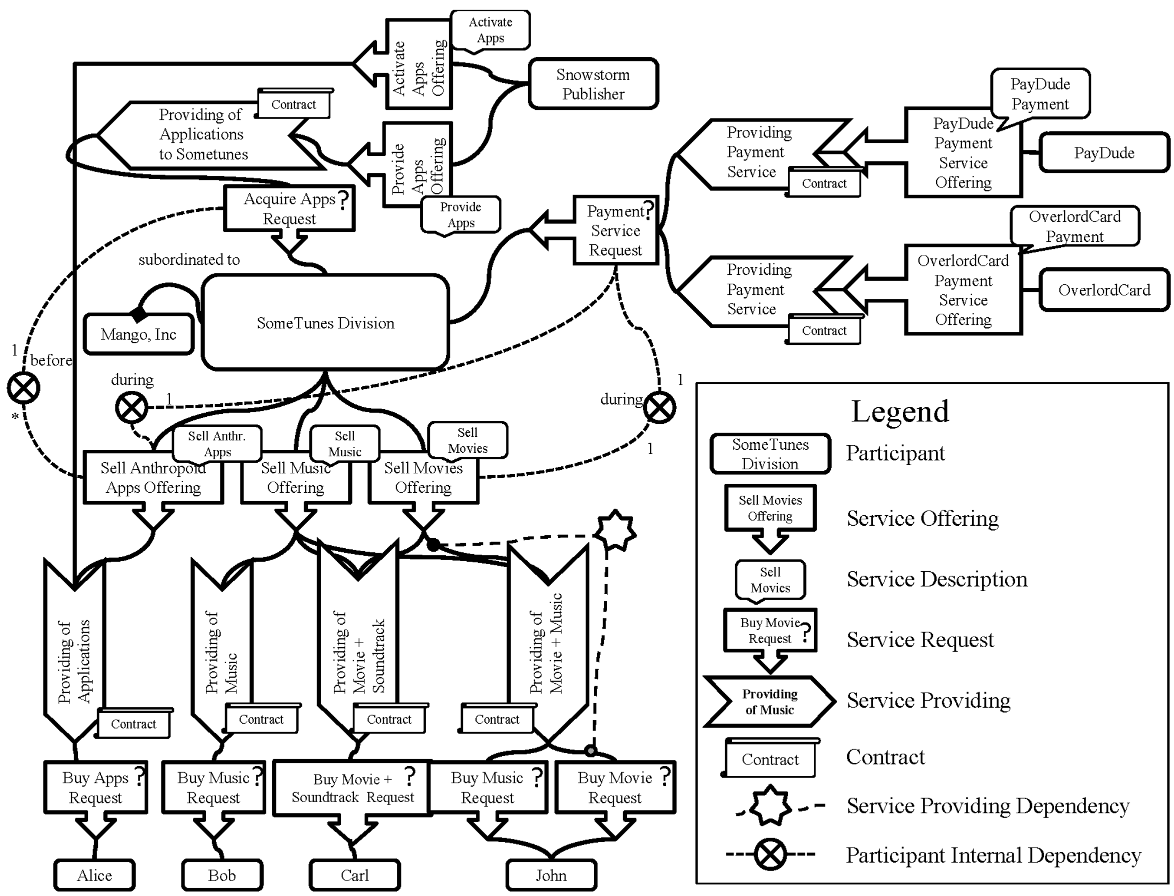

Figure 3 An example of a service network model [7]

Service network models come in two types. *To-be* service network models represent a hypothetical constellation of interconnections between the participants and serve as high level specifications for the construction of the business processes and service compositions. *As-is* service network models represent the current state of an existing service network. Both to-be and as-is service network models are aligned with the business processes and service compositions that specify the execution logic realizing the actual service exchanges. The enactment of service network models is based on a stack of Business Process Management and Service Oriented Architecture technologies, as shown in Figure 4.

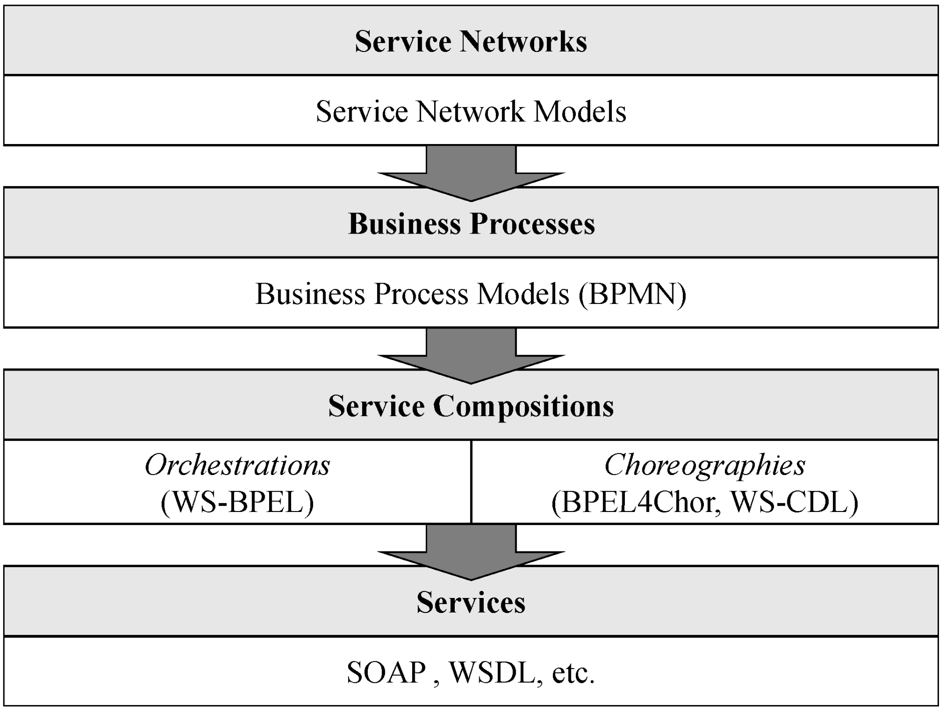

Figure 4 The technology stack for enacting service networks

The artefacts at the different layers of the technology stack are complementary, in that they describe different aspects of the service networks and the business processes that realize them. For example, service network models represent the interconnections between the participants in terms, e.g., of contracts. BPMN models, instead, specify the operational details of the business processes. In [7] we perform an initial investigation of the synergies and differences between service network and business process models, outlining the correspondences between the constructs of the two, as well as discussing which constructs of service network models cannot be explicitly mapped to the constructs of BPMN.

2.3 Views of Service Networks

The modeling of different *views* of service networks is a key ingredient for their efficient management. In [8][3] we consider two complementary types of service network views, namely *offering-centric* and *global*, which are defined on the basis of the service network modeling notation introduced in [7] and discussed in the previous section.

The offering-centric view of a service network focuses on the interconnections of one selected participant, called the *core participant*, and one of its service offerings, named the *core service offering*. The view furthermore requires representing all the participants and their service offerings which are needed by the core participant to produce the *core service offering*, and all the participants consuming the core service offering. Altogether, an offering-centric view of a SN contains the strongly correlated sub-network formed by the core participant, the suppliers that are "upstream" for the core service offering and its customers.

The participants other than the core participant can be marked as *strategic partners*, *enablers* or *end customers* in order to differentiate the economic entities that constitute a service network, based on the characteristics they exhibit. The purpose of this view is to provide the means for performance analysis on the service networks and their participants by studying the impact of strategic changes on participants and on the service network as a whole. This view helps a business analyst to better understand the dynamics of the service network and pinpoint areas for improvement.

3

The offering-centric view can be enriched with additional constructs that are needed for the performance analysis, namely Key Performance Indicators (KPIs) and Key Performance Objectives (KPOs).

In contrast to offering-centric views, which present only a subset of the available information about a service network, global views represent the totality of information available to a business analyst. Global views have been thoroughly studied in [7], and have several applications. A global view may result from the composition of several offering-centric views in order to, for example,

1. *combine* the service offerings (e.g., the core service offerings of different offering-centric views) into “bundled” service offerings,
2. *replace* multiple service relationships by only one which would satisfy the super-set of the service requirements of the formers and achieve better contractual conditions, and
3. *identify* which equivalent service requirements are needed by a participant for creating multiple service offerings and consequently replace multiple service relationships that previously satisfied those service requirements by a single one.

The capability of correlating information presented in global and offering-centric views and to seamlessly move from one view to another is fundamental for the management of service network models. To facilitate this process, the work of [8] investigates how to *project* offering-centric views from global ones and to *integrate* multiple offering-centric views into a global one. In particular, the work discussed in [8] contributes to the state of the art of SNs by:

- Introducing offering-centric views.
- Presenting projection mechanisms for extracting offering-centric views from global ones.
- Presenting integration mechanisms for aggregating distinct offering-centric views in a single, global one.

2.4 Hybrid Simulation Modeling

By synthesizing specific simulation techniques for the logical and physical view on service networks (see introduction), in [9] we aim to develop and explore a novel *hybrid service network simulation* approach that is able to predict, analyze, optimize and tune the performance of service networks and their resources, including software services and human operated services. Our holistic, hybrid simulation framework is firmly grounded on existing simulation techniques that have been widely used in process and system modeling and simulation.

More specifically, three major simulation paradigms, namely System Dynamics (SD), Discrete Event Simulation (DES) and Agent Based Modeling (ABM) have been selected and integrated into our hybrid simulation approach:

- SD entails the study of information-feedback mechanisms of industrial activity to show how organizational structure, amplification (in policies), and time delays (in decision and actions) interact to influence the success of the enterprise. In its basic form, SD analyzes feedback loops and the emerging behavioral effects, such as exponential growth or decline that result from them. SD models populations as discrete actors and conceptualizes processes in terms of aggregated stock (resources at different states in the processes) and flows and constraint information.
- DES modeling analyzes system changes after a specific time interval or incoming event where between any two events/time intervals the service system remains stable. DES models are defined in terms of entities, resources and block charts describing entity flow and resource sharing. In DES models, entities (e.g. people, tasks or messages) passively travel through the block of flowcharts, where they could be delayed, stopped, processed, etc.
- ABM modeling simulates the operation and collocations between autonomous agents. While each agent has its own individual perception and incomplete information of an end-to-end

process, they are able to communicate and share information with other agents. The behavior of an agent is defined by its internal state, which is a cognitive structure that determines what action the agent takes at time t, give its perception of the environment.

Our work in [9] follows the example of existing approaches that combine these three techniques into hybrid dynamic models, which represent both direct and implicit feedback loop-based interactions between components. We rely heavily on simulations to run and analyze different scenarios that consider various service network configurations and/or resource allocations in a virtual environment. A case study is provided to demonstrate how performance-related business and isomorphic technical aspects of service networks can be accurately modelled and simulated by this hybrid simulation approach.

3 Service Network Analysis

3.1 Value Analysis

The growth of service economies coupled with the evolution of information technology have increased the complexity of service companies in a world of interactions and partnerships. Large and vertically integrated firms are replaced by value-creating service networks. Service networks consist of interdependent companies that use social and technical resources and cooperate with each other to create value.

Various approaches have been proposed to measure the performance of service networks. In [10] we study the impact of strategic changes on performance, both at the level of the network as well as its participants. In particular, we introduce an analytical model and associated simulation tool with the goal to optimize value and help analyzing dynamic "what if" questions such as:

- What is the impact of setting optimal – for one participant – prices on the performance of the other participants, as well as the entire network?
- What is the impact on the performance if a new participant suddenly enters the service network?
- Are there any equilibrium strategies among the participants that eliminate their conflicts of interests?

The key observation enabling this analysis is that participants' value depends on their expected profits. Expected profits express the additional value that will be accrued by the relationship levels a participant develops when it sells goods and services to other participants or to the end customers. This value is related to its intangible assets and on the degree of satisfaction it obtains from its customers. We use a System Dynamics approach to analyze the behavior of a complex system (car repair service network) over time. System dynamics tools allow modelers to succinctly depict complex (service) networks, visualizing processes as behavior-over-time graphs, stock/flow maps, and causal loop diagrams. These models can be tested and explored with computer simulation providing for example better understanding of the impact of policy changes (e.g., through animation of the behavior of service systems) and facilities for sensitivity analysis.

In [10], we have adopted for these purposes the iThink[4] tool to investigate the fluctuation of value under different circumstances. The results of these simulations provide predictions about the future behavior of the service network in order to increase its adaptability to the changes of the environment and enable network participants to determine the most profitable collaborations and consequently attract new ones. We show that the interactions among the participants of a network by necessity force them to reach equilibrium, otherwise the network will collapse.

In particular, we perform simulation experiments to analyze our model making use of 4 scenarios: first, we apply our approach to the car repair service system to examine the network's evolution over

[4] http://www.iseesystems.com/softwares/Business/ithinkSoftware.aspx

time. Second, we apply our methodology to a transformed network (considering IT-based improvements) and determine the time interval in which we observe positive effects in profitability in the transformed network compared to the initial one. We also determine which of the participants benefit from the transformation and which not. Third, we consider a model in which the group of dealers is replaced by a new one that offers more complementarities to the end customers without increasing the mean repair price. We examine the value of these dealers and the value of the entire service network. Fourth, we investigate Nash equilibrium strategies between the car manufacturer and the dealer.

3.2 Performance Analysis

Organisations are becoming increasingly interested in understanding the operations of service networks as a means to adapt to the ever-changing business environment. Services are considered one of the most important business developments which have emerged to the forefront of our economic development over the last decade. We now live in a 'service-dominant' economy, which has become increasingly complex and intertwined in service networks and business transactions [11]. Consequently, the difficulty is that in the modern or virtual organisation, service delivery is dispersed across complex service networks. Thus, there are greater pressures on service systems to deliver higher quality and more efficient service as management continue to invest in information systems (IS) and business applications. However, there are major concerns as to the lack of research efforts to examine methods to successfully manage the complexity of service networks. Through an extensive literature review, in [12] we discuss the importance of service network performance analytics (SNPA) within BPM to support the service-dominant business environment. In addition, [12] presents evidence for the need to conceive tools and techniques to manage the complexity of service networks without jeopardising business transactions and the quality of service networks.

There are several reasons to undertake this line of research. For example, in order to deliver effective services, providers are being advised to 'innovate' their service delivery systems. Innovation in this context often refers to new technologies, techniques or restructuring service improvements. However, the difficulty is that in the modern organisation, service delivery has become a relative *invisible* task across service networks. Management must attempt to develop a greater understanding of service processes to identify where improvements may be made by employing BPM. The network approach ultimately makes service innovations and service (re)configuration more difficult to implement, monitor, and report on service *performance*. This is necessary, as performance is one of the central concepts of business. As services dominate the business landscape, understanding performance, and more specifically KPIs, is critical. However, the complexity and interactive nature of service systems makes it difficult to truly understand the nature of service performance. The work in [12] discusses the importance of service network analytics and discusses the need to focus on KPIs methods while modeling service network behaviour.

In particular, in [12] we adapt Mitchell's description of a network [13] and apply it to a service-dominant environment to imply *a specific set of linkages among a defined set of actors, with the additional property that the characteristics of these linkages as a whole may be used to interpret the service behaviour of these actors involved*.

The interaction patterns exhibited within service networks are of critical importance to service simulation and performance analytics. In [12] we demonstrate a number of service performance modeling techniques and we discuss how social network analysis allows us to explore how to analyse, design, and/or reconfigure service networks across distributed communication and collaboration structures. In addition, we adopt *actor network theory (ANT)* [14] as one of core theories upon which we can examine service relations and their effects on the performance of service actors (for example, people, organisations, and IS) and provide us with insights on service dynamics and resulting performance.

We further identify the need to incorporate service performance analytics within BPM to enhance the manageability of service networks. This is central to the discussion in [12], considering that, if managers fail to report service performance, it is increasingly likely that resources will be misallocated, innovative ideas will be rejected, money will be wasted, quality of service will be jeopardised and service reputation will be at risk.

4 Conclusions

Service networks accommodate well-defined, collaborative end-to-end processes directed towards value co-creation, such as payment processing, and, shipping and tracking. Indeed, there is a need for explicitly identifying and managing fine-grained properties of end-to-end processes such as bQoS, and aggregated QoSs, and partner Key Performance Indicators (KPIs), to guarantee the correlation of end-to-end process properties and achievement of network-level objectives. These considerations give rise to modelling and simulation concepts and mechanisms that span from logical end-to-end processes in service networks, to back-end system resource-level support.

This deliverable bundles various articles that collectively define the basic fabric for modelling and simulating service networks. This deliverable has been logically organized in two complementary parts: Modeling (part 1) and Simulation (Part 2). In particular, part 1 presents a notation for representing and views for visualizing networks models, while defining a mapping between service network and business process models. In addition, we introduce a modelling approach that draws upon system dynamics to model and better understand the dynamics of service networks to assist network designers in assessing different network configurations and resource allocations, and understand the impact of changes. Part 2 of the deliverable focuses on the application of simulation techniques for two interrelated types of network analysis: value and performance analysis.

Clearly, the results presented in this deliverable are core results in nature. In particular, we plan to collaborate with JRA-1 WPs to establish relationships between the SN lifecycle and the S-Cube SBA Lifecycle (JRA-1.1), predict the quality of service resources in SNs, and, monitor the performance of SNs (JRA1.3).

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