TOWARDS PREDICTIVE SELF-ADAPTATION IN SOC
A Value-based Perspective

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Abstract: Self-adaptation represents one of the main research challenges in Service Oriented Computing. More specifically, predictive self-adaptation attempts to anticipate actions for reacting to potential changes in a system, over time. Nevertheless, the execution of different adaptation strategies on the operational level can produce an unexpected impact on the organizational level. Predicting this impact, mainly in terms of time and cost involved in the adaptation, might be useful to enhance the decision-making process in a business strategic/tactic context. This paper presents some of the challenges in predicting the impact of adaptation strategies in a service provisioning scenario, from a value-based perspective.

1 INTRODUCTION

The increasing interest in self-* properties[1] in Service Oriented Computing (SOC) has heightened the need for reconciliation between technology and methods towards autonomy in service management (Papazoglou et al., 2007). Of particular interest and complexity is the self-adaptation of services, observed from a predictive perspective, which involves prospecting the impact of future multi-domain changes on the business strategy level, and thereby taking decisions to minimize possible negative return following them. There have been several investigations into available requirements, strategies and implementation techniques for self-adaptation in SOC (Benbernou, 2008).

These aspects rely upon monitoring mechanisms for change detection. The articulation of adaptation strategies typically complies with intra and inter-organizational rules and/or policies (Gordijn et al., 2008). The scope of these rules can range from the IT level to the corporate levels, setting the rules of the game, which constitutes the core of the service governance process (Marks, 2008).

Although considerable research has been devoted to service monitoring and adap-tation, rather less attention has been paid to investigate and measure the impact of an adaptation strategy (or a combination of strategies) on the organizational level. In other words, the service adaptation process can be followed by a reconfiguration of organizational stakeholders. Paraphrasing Meadows' philosophy (Meadows, 1999) and Chaos Theory (Poincaré, ca. 1900 and Lorenz, 1960), even a small shift produced by a strategic intervention within a complex system can produce significant changes in its whole structure. Conversely, the degree of freedom of a system is defined by its own rules, and the power over these rules constitutes the fundamentals of a governance process. However, if these rules are somehow flexible, it implies dynamism in the rearrangement made on the adaptation strategy level. In this paper we report on some of the challenges around the specification and deployment of predictive and self-adaptive services. These challenges comprise not only technical issues, such as checking whether the resulting adaptation complies with technical and corporate rules or not (Verhoef, 2007), but also attempting to forecast the profitability produced by a possible selected strategy. Reduction of the cost and time involved in the required decision-making process (by minimizing human intervention) might be particularly important to react rapidly in highly dynamic and competitive markets, and thus, represents the central motivation of this research. Thus, to cope with this issue, the goal of this re-

[1] Self-configuration, self-adaptation, self-healing, self-optimization, self-protecting are commonly referred to as self-* properties in computer systems in general.

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search is to provide a framework to guide the decision-making process on the adapta-tion strategies set, whereby the organizational stakeholders could be reconfigured, preserving a value-based perspective goal (i.e. to maximize profitability for all the organizational actors involved).
The plan of this paper is outlined as follows. Section 2 presents the considered problem space, by means of interrelated research questions. In Section 3 it is proposed a set of candidate approaches and methods that compose the solution space to be deployed. In Section 4, it is discussed potential applications of this work in two case studies. Some related work is presented in Section 5. Last, Section 6 brings some discussion and outlook for this research.

2 PROBLEM DEFINITION

The following research questions outline the problem space in focus. They are decomposed into sub-problems, enumerated in ascending order of relevance, according to the purpose of this work.

Research Question 1. *What are the adaptation requirements for multi-supplier IT services?*

Assumptions: for the purpose of this study, the term "adaptation requirements" may be defined as a set of properties that the adaptive service application should satisfy (Benbernou, 2007). Besides, "IT services" are defined as infrastructure services configured from a business value model perspective (Gordijn, 2002) (Gordijn et al., 2007).

Problem Decomposition. *What are the "change" patterns in service management? How these changes are monitored? Which of these change patterns allow automated solutions? What "action patterns" follow these change patterns? What policies govern these action patterns? Which are the most relevant changes in terms of impact produced (e.g. in terms of cost and time)?*

Potential answers for these questions can be classified according multiple dimensions, including:
What? (Rules/Policies and Governance);
Where? (Physical and logical layers);
When? (Temporal reasoning);
How? (Causality-effect and correlation analysis);
Who? (System automation or human intervention)
These same dimensions will also be applied to classify the outcomes from the next questions.

Research Question 2a. *How to monitor a value constellation and its coordination processes?*

Assumptions: a "value constellation" can be defined as a *collection of enterprises that jointly satisfy complex consumer needs* (Gordijn, 2002).

Problem Decomposition. *What is the purpose of the monitoring task? What kind of monitoring information has to be gathered? How can the monitoring information be specified? What implementation methods and techniques are currently available for monitoring of SOA-based applications? How can the monitoring information be integrated?*

Research Question 2b. *How to adapt a value constellation and its coordination processes automatically?*

Assumptions: the degree of automation here is strictly dependent on the outcomes of the **research question 1**. It is still not clear to what extent should we minimize the human intervention in business-related decision. As soon as new adaptation problems arise, new solution patterns can be discovered, mined from human knowledge input in combination with existing solution patterns.

Problem Decomposition. *What rules/policies govern the adaptation process? What are the organizational goals behind the rules? How can these rules be specified? Who defines these rules? What methods and techniques exist for implementing self-adaptive services? How can these rules be specified and configured from a business value perspective?*

Research Question 3. *How to coordinate the reconfiguration of a provisioned IT service bundle offered by a constellation?*
Assumptions: "organizational stakeholders" can have conflicting or convergent goals, observed from different perspectives. For instance, in the intra-organizational level, competitions can represent a source of emergent behaviour, weakening efforts to reach a common goal. Conversely, collaborations might potentially produce the opposite effect. The same applies for the inter-organizational level, where different organizations play a *win-win game*, in which collaboration and competition are blurred by high level system goals that include survival, resilience, differentiation and evolution (Meadows, 1999).

Problem Decomposition. *What is the extent and impact of the adaptation process on organizational level? How can this impact be measured? Does this*

process require reconfiguration of stakeholders (design for players or "tactical design") or reconfiguration of the rules (changing the whole game or "strategy design")? What theoretical approaches exist for organizational modelling, and more specifically for strategy reasoning and decision-making processes in multi-parties service provisioning? To what extent are these approaches currently evaluated? What practical issues and enabling technologies are required in their corresponding implementation? How to ensure that the chosen adaptation strategy/tactic complies with intra and inter-organizational governance rules?

3 RESEARCH DIRECTIONS

The following research directions outline our approach to deal with the before mentioned problems. They include some expected results and validation techniques.

Solution Direction 1: research question 1 will be addressed both conceptually and empirically. The conceptual part will be based on a systematic literature review on self-adaptive services. The objective is to identify the most impacting sources of change as well as its corresponding adaptation strategies, and which of those allow automated solutions. Causality, effect, cost, propagation over the time and correlations can represent some of the dimensions whereby the impact can be measured. Qualitative reasoning (QR) can be used to explicitly model causal dependencies between quantities (Bredeweg and Struss, 2004). QR also includes the use of ontologies for expressing and formalizing relationships between concepts. Ontologies can easily be adopted as artifacts in the implementation architecture. This represents a practical advantage over pure mathematical expressions which, although may provide more accurate and unambiguous descriptions of the problem in question, can imply additional cost, concerning the refinement operations necessary to map it into the implementation layer. Regarding technical aspects, recent work has been done on investigating the use of the Web Ontology Language (OWL)[2] on solving qualitative reasoning problems (Liem, 2005). In spite of some limitations of expressiveness (expected to be improved in the upcoming OWL2 specification), a model developed in OWL allows searching and sharing of knowledge on the Web, whereby corporate business intelligence can be improved.
The empirical part will be performed by quantitative analysis of data retrieved from the practical experiences in the case studies and from a survey sampling.

Expected Result: an ontology of change patterns and adaptation strategies (in composite services realizing a value constellation), and a ranking of the most relevant ones.

Validation: can be achieved by means of intersection of research methods (in this case, a combination of surveys, structured interviews, a systematic literature overview and a proof-of-concept tool to be applied in the case studies).

Solution Direction 2a/b: research question 2a and **2b** will be addressed jointly, considering that service monitoring and adaptation are closely related. Ordinarily, these tasks are linked by adaptation rules or policies that specify what should be done under which condition. Current research suggests some kind of Event-Condition- Action (ECA) rules for specifying these policies (Paschke and Bichler, 2008), but they are typically specified on a rather low level (i.e., close to the programming code). On the other hand, recent work has been done on specifying methods to support business analysts in designing controls against opportunistic behaviour in network organizations, from a value-based perspective. This approach, named *e³control* (Kartseva, 2008), can be considered as a starting point in this study to define high-level rules and policies for service governance. A possible solution to connect these two worlds can be an extension of the referred value-based control approach toward the ECA rules level, by specifying intermediate layers, in different abstraction levels and a set of refinement operations to integrate them. This should make the rules easier to design, maintain and reuse.
A monitoring strategy should be done in order to collect external events and information produced in the service execution environment. Performance checking, failure reporting and analysis of the compliance with Service Level Agreements (SLA) are the outcomes of this task. Several approaches have been identified for monitoring different operational layers in service-based applications. These layers can include monitoring of web services and service compositions, Business Activity Monitoring (BAM), Process Mining and Grid Monitoring (Benbernou, 2008). The monitoring information collected from these layers must be integrated to produce a consistent view on the

[2] http://www.w3.org/2004/OWL

overall system performance. To date, proposed industrial standards in the Web Service Management area include Web Services Distributed Management (Wilson and Sedukhin, 2006) and Web Service Level Agreement (Ludwig et al., 2003). The former provides some mechanisms to guarantee consistency of service compositions, and deliver status notifications when a particular activity is completed or a decision condition is reached. The latter provides a description of IT-level and business process-level parameters (e.g. response time and throughput), the quality of service agreed to be delivered by the service provider, besides some penalties to be applied in case of depreciation or failure to meet these requirements.

Expected Result: a rule-based system for self-management of value constellations.

Validation: by means of an experimental prototype. **Solution Direction 3:** there are several possible ways of handling the problems around **research question 3**. Methods, models and theories from the field of organizational modelling have been proposed to deal with change management in general. The Management and Business Encyclopedia[3] have classified these approaches along 12 disciplines. For the purpose of this research, six of them were selected to classify potential candidates to be considered the solution space, as follows: *Organizational Change, Communication Aspects, Value-Based Decision-Making, Intangible Knowledge, Strategy and Supply Chain Quality*. None of the existing approaches cover all of these aspects. Theoretically, merging them might result in a more complete solution. Practically, the high level of complexity involved on implementing such a combination may represent an additional problem not subsumed in the scope of this research. Consequently, one of these theories will be applied. Approximate matches include: Chaos Theory (Poincaré, ca. 1900 and Lorenz, 1960), Game Theory (Nash, 1950), Contingency Theory (Vroom and Yetton, 1963), Action Learning (Revans, 1969), Strategy Map, originally referred to as *Balanced Scorecard* (Kaplan and Norton, 1992) and Value Mapping (Jack, 2001).

Expected Result: a formal framework for reconfiguration of service bundles.

Validation: validation can be achieved by formalization and proof. Feasibility can be checked by means of experiments in the case studies.

[3] http://www.12manage.com

4 CASE STUDIES: MUSIC AND ENERGY INDUSTRIES

It is important to highlight the case studies in which this research is currently being applied. The following description includes who they are, their attributions, future scenarios and particular interest in this research.

SENA[4] is an Intellectual Property Rights Society (IPR), appointed by the Ministry of Justice of the Netherlands, designated to execute the

Neighbouring Rights Act in the music sector. It states that *formally a user of music must obtain permission from the right holders (the creators of music) to play it in public. By virtue of the Copyright Act and the Neighbouring Rights Act the creators of music have assigned their right to grant permission for the use of their music to SENA (performers and producers) and to Buma/Stemra*[5] *(lyricists and composers).This permission, called a license, is issued by both organizations on condition that the user of music pays remuneration for this. The rate depends on the nature of the use and the space in which the music is played*[6].

Although **SENA** pricing strategy considers statistics taken from the 20 biggest radio stations in the Netherlands, emergent complaints from IPR users (i.e. cafes, clubs, restaurants, supermarkets etc.) have revealed that these users are interested in paying only for the tracks they use (i.e. pay-per-play scenario). Consequently, a counting and monitoring mechanism should be deployed in order to charge each IPR user more accurately.

According to the current SENA requirements, a new business model was designed. The business model is based on the e^{3}value methodology (Gordijn, 2002). It includes the main actors and the objects of value they exchange to each other. The main organizational actors in this scenario comprise:

Receivers: they represent the starting point in the value-object exchange. A *receiver* is an actor who wants to satisfy a need (in this case, to broadcast background music). Thus, since *receivers* want to use music to get benefits of it, they are also *IPR users*.

Background Music Providers: they provide specialized background music. In this sense, whenever an actor requires specific background music, a BMP can exchange background music for a fee.

[4] http://www.sena.nl

[5] http://www.bumastemra.nl

[6] *Statement on Music Licenses and Remunerations*. Source: SENA Annual Report 2007 (minor editing).

Intellectual Property Right Societies: IPR Societies are entities performing mainly two roles: collect fees from each played or copied track and partitioning of these fees to the *IPR owners*. Thus, on one hand, whenever a track is played or copied, a fee must be also paid. This fee is related with the public use of music (tracks). Thence, if an actor publically provides music, it has to pay for the right of providing music (i.e. making profits by exploiting IPR). The way in which actors get that right is paying fees to *IPR Societies* for each played or copied track. On the other hand, *IPR societies* partition fees to the *IPR owners* according to collected fees. This partition of fees is based also on track's features (i.e. who the owners are and how many times the track was played or copied).

Right Owners: they constitute the set of actors who perform a specific track. In this sense, "performing" is not only related to playing tracks, but also encompasses tasks like writing lyrics, producing and publishing a track.

Once described the main actors and their roles, the interaction between them can be specified. As mentioned before, the *receivers* constitute the starting point, as they request for broadcasting background music which is provided by the *background music providers*. This relationship is summarized as follows: a *receiver* gives a fee to a BMP and gets in return background music.

A BMP could provide background music in two ways: by delivering hard copies or a stream of tracks. In this sense, hard copies can be considered as physical devices in which the *receivers* store tracks provided by the BMPs, whereas a stream is a flow of tracks that the BMP delivers to the *receivers* using internet-based technology. Thus, the main difference between these two ways of providing music is either allowing storing tracks at the *receivers'* side or not.

This main difference has generated two similar value models. If the BMP delivers hard copies, it must pay to *IPR Societies* which collect fees about replicating music, thus making copies of tracks. On the other hand, when providing streams, the BMP must pay to *IPR Societies* which collect fees related with making a stream available to the public (Figure 1).

Receivers have to pay also *IPR Societies* for providing music to the public. Thence, they pay mainly two distinct *IPR Societies* (although it does not mean they pay twice). Paying BUMA/Stemra is about the copyright that *publishers, composers,* and/or *lyricists* hold, whereas paying SENA is related to the rights of the performing *artists* and *producer*s. All the process described above is associated to collecting fees. Therefore the next step is to partition all those fees. As it can be observed in Fig. 1, the *IPR societies* partition fees to a set of *right owners*. This set of *right owners* is composed mainly by *artists*, *producers*, *music publishers*, *composers* and *lyricists*. However, there is a clear division about who partition fees to whom. Again, SENA only partitions fees between *artists* and *producers*, whereas BUMA/Stemra does the same for *publishers*, *composers* and *lyricists*.

Finally, since *receivers'* claim is about pay-per-play, both models (the model for hard copies is similar to the model depicted in Fig. 1) introduce a new activity that must be performed to allow pay-per-play service. This new activity is about *logging* each track the receivers play. Consequently, to have access to the pay-per-play scheme, receivers must provide a log with the tracks they had already played. Regarding the trust aspect, security mechanisms will be further specified.

From a technical perspective, if the Key Performance Indicators (KPIs) in the provisioning of streaming audio drop below the Key Quality Indicators required by the receiver (e.g. availability, audio quality and response time), some service adaptation should be done in order to optimize the overall network performance (Toktar et al., 2007), (Dalal et al., 2007).

From a business perspective, the music industry has been dramatically changed as far as new technologies for use and distribution of digital music scatter throughout the Internet. New digital music retailers/providers have to play a wild game to adapt themselves to this new market and offer value-added services for distribution of digital music. Therefore, new business and technology strategies become essential for the sake of profitability whereby survival in this wild game might be guaranteed. *It is crucial the enforcement of Intellectual Properties restrictions, and to promulgate effective copyrights and licensing for music distribution, and organizations involved in this initiative must consider new technologies and strategies for monitoring piracy* (Bockstedt, Kauffman and Riggins, 2006).

The second case study is **ECN**[7] (Energy Research Centre of Netherlands). This organization develops knowledge and technology for a sustainable energy system and transfers it to the market, which costumers include the Dutch government, European Union and industry (national and international).

ECN envisions a scenario when *the houses of the future will not only be energy-neutral, they will generate energy which can be used elsewhere*

[7] http://www.ecn.nl

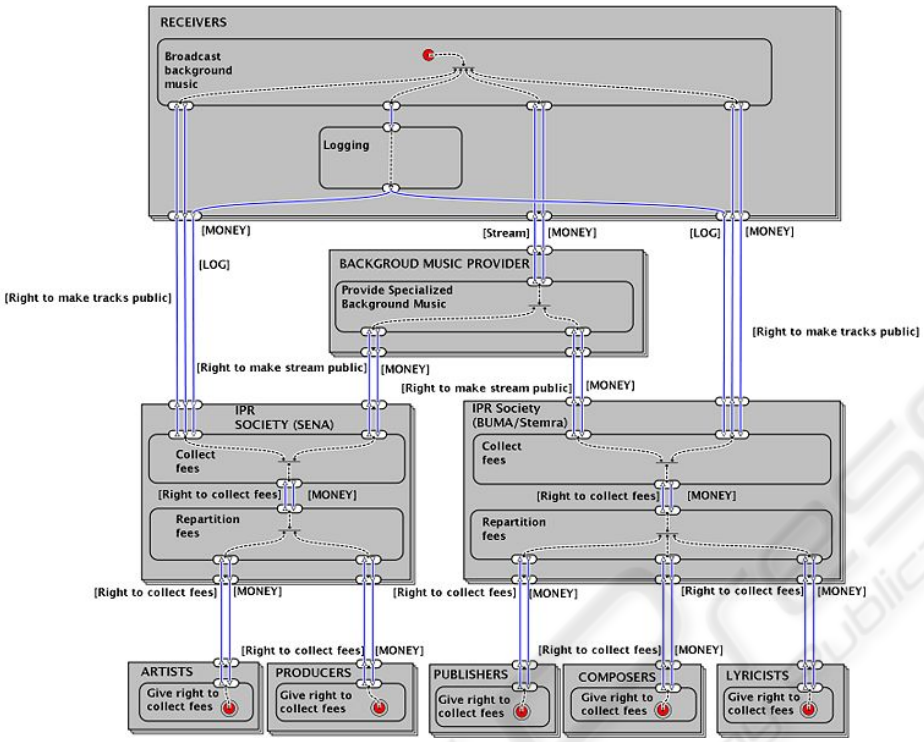

Figure 1: Value model for the Music Industry: the stream value exchanging case.

effectively, through the efficient exchange of electricity and heat. This will require intelligent and self-managing electricity grids[8]. It means bringing the electricity service to a market with new small players (e.g. households and small scale generators). This requires a portfolio of such households and generators that could be easily reconfigured, not only in terms of balancing services, but also supporting services (e.g. communication, processing power services, etc.), besides prediction over the results from the profitability analysis of this new scenario. The design of a new business model for this scenario is part of future steps of this research.

5 RELATED WORK

The four pillars sustaining this research are: service monitoring, service adaptation, organizational modelling and governance (IT, SOA and Corporate).

Several approaches have been identified for monitoring of service-based systems (Benbernou, 2008). They encompass basically mechanisms for Monitoring Web Services and Service Compositions, Business Activity Monitoring (BAM), Process Mining and Grid Monitoring. It would seem, nevertheless, that further investigations are needed so as to integrate available methodologies and technologies across all the service-based application layers. WSDM (Wilson and Sedukhin, 2006) and WSLA (Ludwig et al., 2003) represent some of the recent standards proposed to fulfil technical needs for the integration of the monitoring information.

Regarding the adaptation process, among several research directions, some approaches have emphasized the provisioning of correctness criteria to check system integrity after an adaptation strategy is executed, from a technical perspective (Weigand, van-den Heuvel and Hiel, 2008). In the opposite way, adaptation in the business collaborations has also been addressed (Orriëns, 2008). Still, cross-layer dependencies of adaptation strategies remain as open issues.

Concerning the before mentioned organizational modelling theories, recent work has focused on implementing them in service-based scenarios. The following initiatives comprehend some of them: enterprise strategy management using chaos theory (Levy, 1994), (Hao et al., 2008), (Zhao and Li, 2005), application of game theory in business process reengineering (Zhang et al., 2008), (Li,

[8] *Constructing a Sustainable Future*. ECN Annual Report 2007 (minor editing).

Chen, and Cui, 2008), contingency theory in IT strategy plans (Lee, Miranda and Kim, 2004), (Croteau and Raymond, 2004), modelling of virtual communities under the perspective of action learning (Parenthöen, Buche and Tisseau, 2008), (de Moor and Weigand, 2007), and the inclusion of the stakeholder value perspective in the configuration of strategic business initiatives, using strategic maps (Sahu, 2004), (Chien-Chih, 2007) and value mapping (Moore, 2008). Nonetheless, their scope is still restricted to distinct abstraction layers, stressing the need for an integrated approach.

Last, recent contributions have been acknowledged in the field of service governance. They range from value-based controlling mechanisms over organizational networks (Kartseva, 2008) to quantification analysis of governance rules in the IT level (Verhoef, 2007). Challenges in this area include the development of a unified model for SOA policies that could integrate business process, technology, design, and runtime policies. Such a model could be implemented as governance collaboration tools to explore collective intelligence.

In short, these four pillars still lack a common ground of integration and interoperability, which sets the perspective orienting this research.

6 CONCLUSIONS

The purpose of this paper was to identify some of the gaps in self-adaptive services research. Its outcome comprised our research design and proposal, hereafter focused on investigating the impact of service adaptation strategies on the organizational level, where the crucial decisions are carefully analyzed. The urgent need for solution alternatives to be applied in real world applications (e.g. the Music Industry and the Energy Management Sector), reinforces the motivation for realizing this research.

This work in on its early stage and the prototype to be produced for addressing the first research question is currently under development. Future steps include combining ontology engineering and qualitative reasoning techniques to specify and analyze causality/effect and correlations between change and adaptation patterns in service bundling. These patterns are currently being catalogued and will be contrasted with empirical data extracted from the case studies.

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