Solving service ecosystem governance

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***Abstract*—The present way of doing business increasingly requires enterprises (and other organisations) to collaborate with each other; networked business allows enterprises to focus on their key competences and still capture market share with added-value, composed services jointly with trusted business partners. However, the present solutions for setting up new collaborations are based on ad hoc methods, or require integration through shared computing and communication platforms. These solutions leave collaborations with major risks on not detecting failures, functional or non-functional, breaches of trust or contractual state, or without systematic support on reacting to the changes in the business environment.**

This paper proposes service ecosystem governance principles, which are illustrated through the example analysis of the Pilarcos framework for service ecosystems. Service ecosystem governance supports correctness in dynamic collaborations despite strong autonomy of the partners, adaptability to changing business situations, and the manageable evolution of the service ecosystem that is necessary for sustainable networked business.

***Keywords*-service ecosystems, service ecosystem governance, ecosystem life cycles, Pilarcos framework**

I. Introduction

The current business landscape is characterized by commoditization and shortened product life spans [1]. To increase revenues in this landscape, many enterprises are moving to service-centric business models and utilization of electronic services. Public organizations operating on domains like health-care and government provide and utilize electronic services as well, for increasing their coverage, efficiency and customer satisfaction. Even individuals consume electronic services provided by governmental bodies, commercial actors, and communities of interest. These services include different forms of information sharing and social networking services.

Service-centric business takes place in service ecosystems. A service ecosystem is a socio-technical, complex adaptive system. Its technical aspects support contract-governed composition of software agents, i.e. computational services, where the services can be provided by independent ecosystem members. On the social level, business or legal concerns are relevant. Here, providers, users and other stakeholders of these services or collaborations are noted as ecosystem members. Thus, members can be enterprises, institutions or individuals. The ecosystem also involves its supporting infrastructure with management services and related knowledge repositories.

Service ecosystems may emerge spontaneously due to a common interest or demand, or as a result of long-term strategic planning. Examples of service ecosystems include software ecosystems (e.g. those provided by Amazon, Nokia, or Apple), electronic business networks (e.g. eCommerce platforms, supply chains and virtual organizations), cloud computing platforms and social networking platforms (e.g. Facebook, LinkedIn or MySpace).

The present way of doing business increasingly requires enterprises to collaborate with each other; networked business allows them to focus on key competences and still capture market share with added-value, composed services jointly with trusted business partners. However, the present solutions for setting up new collaborations are based on ad hoc methods, or require integration through shared computing and communication platforms. These solutions leave collaborations with major risks on not detecting failures, functional or non-functional, breaches of trust or contractual state, or without systematic support for reacting to changes in the business environment.

For supporting business in future service ecosystems, a transition from ad hoc solutions to *sustainable service ecosystems* is needed. Sustainability means capability of a service ecosystem to support continued viability[1]. The viability of a service ecosystem depends on the level of business-supporting capabilities it provides for its members. A viable service ecosystem must provide capabilities for *a)* efficient utilization of core competencies, *b)* opportunistic and flexible business networking, *c)* supporting progressive business environments, and *d)* efficient business decision-making. Continued viability means that these capabilities are provided by a service ecosystem without interruption. Our hypothesis is that continued viability can only be attained through service ecosystem governance.

This paper proposes principles for *service ecosystem governance*, which denotes collaborative activities for directing, monitoring and managing a service ecosystem: 1) service production and provisioning, contracting, and regulation processes, 2) management of ecosystem knowledge (models, reputation) and evolution processes, and 3) alignment between ecosystem intensions and governance activities within

[1]Sustainability in the context of software architectures is defined as "An architectural property of a program which allows continued viability" in the Open Knowledge Initiative by MIT.

each member organisation. This goal brings together both interconnecting technical systems and pragmatic management aspects; in other words, technical implementation concepts and business concepts affecting e.g. policies must be handled within the same system, taking into account the differences of these two conceptual layers. The governance principles are illustrated through the example analysis of the Pilarcos framework for service ecosystems [2], [3], which delivers concepts and technologies for establishing sustainable service ecosystems for inter-enterprise collaboration.

Service ecosystem governance supports correctness in dynamic collaborations despite the strong autonomy of partners, adaptability to changing business situations, and manageable evolution of the service ecosystem that is necessary for viable and sustainable networked business. We propose a systematic method for ecosystem description, which has an emphasis on formalizing service ecosystem elements such as life cycles and knowledge artefacts; this facilitates production of consistent service ecosystem models. The resulting service ecosystem models are valuable for potential ecosystem members for defusing risks associated with joining and operating in the ecosystem.

There has been research conducted in the area of enterprise architectures, targeting the definition and governance of complex distributed system architectures. Enterprise architecture definitions concentrate on business-IT alignment and model enterprises roughly from the business, information, system and technology perspectives (see e.g. [4]). The elements described within the perspectives consider the necessary elements for achieving enterprise-specific business goals and strategies.

Current enterprise architecture approaches are not applicable as such for defining architectures of open service ecosystems. Enterprise architectures declare static snapshots of the enterprises' current and future states. In open service ecosystems the elements that are considered, e.g. participants, roles, processes and information, are dynamic by nature, and cannot be defined in static snapshots. Instead, we want to model sufficient consistency and coordination rules for all possible current and future ecosystem states. We achieve this by capturing the sole static elements of open service ecosystems, i.e. their foundational life cycles.

The rest of the paper is structured as follows. In Section II the foundations for service ecosystem governance are identified and elaborated. The Pilarcos framework is described in Section III. We demonstrate the feasibility of the service ecosystem governance approach by systematically applying the proposed method to the Pilarcos framework in Section IV. Section V concludes.

II. Constructing ecosystem governance

Service ecosystems are initiated and maintained for fostering and enabling collaboration between ecosystem members. The members cooperate to reach shared goals and gain added value by utilizing services delivered in the ecosystem. A service ecosystem includes *a)* entities acting in domain specific roles (e.g. as providers and consumers of specific services); *b)* services available for enabling collaboration and co-creation in the ecosystem; and *c)* infrastructure for realizing service engineering and delivery, and ecosystem governance. The Amazon AWS[2] platform, for example, can be considered as a service ecosystem. It consists of entities such as Amazon itself, other organizations, and individuals providing and consuming services available in the Amazon platform. Infrastructure services, such as EC2[3], are utilized by service providers for delivering business services.

We define service ecosystem governance as the collaborative activity of directing, monitoring and managing service ecosystem operation. Governance activities are enacted by ecosystem members in life cycles which define how, when and by whom a certain activity should be taken. In the following, a systematic description methodology for supporting service ecosystem governance is described. The methodology provides means for identifying and defining the life cycles that provide service ecosystem governance.

In the following subsections, we provide the principles for service ecosystem governance: we first describe the relevant concepts, then define a set of perspectives and elements that must be considered when declaring service ecosystem life cycles. The selection of perspectives and viewpoints for identifying and defining the life cycles is similar to methods developed for conventional architectural analysis [5].

A. Ecosystem capabilities and life cycles

Service ecosystems are put together for enabling establishment of collaborations. In service ecosystems, the collaborations are enabled by by service delivery. Collaboration and service delivery are examples of service ecosystem *capabilities*. The ecosystem capabilities define the intension of the ecosystem and deliver business value in the corresponding domain of interest. Ecosystem capabilities can be classified to functional capabilities, such as collaboration and service delivery, and qualitative capabilities, such as trusted interactions. Each service ecosystem may have different selection of capabilities.

For guaranteeing the viability of a service ecosystem, means for directing, monitoring and managing ecosystem capabilities and participation in their fulfillment must be provided. In the methodology we propose, service ecosystem capabilities are governed by associated life cycles.

We define a *life cycle* as a process with predetermined behaviour and roles that is enacted by a selection of ecosystem members. It comprises of a sequence of one or more phases. Each life-cycle phase involves a choreography between ecosystem members responsible for fulfilling the

[2]Amazon Web Services: http://aws.amazon.com/

[3]Amazon Elastic Compute Cloud: http://aws.amazon.com/ec2/

goals of the corresponding phase. The choreographies are comprised of activities that contribute to the fulfillment of ecosystem capabilities. Functional capabilities are instrumented by activities, such as service offer publication, that enable collaboration life cycles. Qualitative capabilities are supported by activities for up-keeping ecosystem knowledge bases and providing flexible technical interaction facilities.

Each life-cycle phase may consume and produce one or more artefacts. An artefact is a well-defined element of knowledge whose intension and semantics are shared by all ecosystem members (i.e. it is a part of a shared ecosystem ontology). Artefacts such as service descriptions, collaboration contracts or business network models are used in service ecosystems for sharing knowledge about the different elements required for and expected from the collaborative activities taking place.

Activities are enacted by actors. An ecosystem *actor* is defined as an ecosystem member taking certain role(s) which are prescribed in phase choreographies. A phase choreography defines the activities, obligations, policies and other kinds of rules steering and constraining the actor behaviour for fulfilling the goal of the corresponding life-cycle phase.

Life cycles may share phases with each other for achieving strict coupling between interrelated activities. Loosely coupled coordination between life cycles takes place through sharing of artefacts. Life cycles have varying scope, affecting the entire ecosystem, specific collaborations or single enterprises at a time. Due to inter-dependencies, their acceptability and correctness must be ensured together; life cycles cannot be handled one-by-one in an ad hoc manner.

B. Identifying ecosystem life cycles

Ecosystem governance is a collaborative activity taken between autonomic entities for guiding, monitoring and managing ecosystem capabilities. As such, it must especially address issues related to the coordination of the collaborative activities, compliance of member behaviour with respect to mutual agreements, as well as dispensations due to illicit or unexpected behaviour. Each ecosystem capability is governed by one or more life cycles. For identifying the necessary life cycles, our methodology utilizes four perspectives. These service ecosystem governance perspectives with respect to ecosystem member behaviour are *1)* coordination, *2)* compliance, *3)* dispensation, and *4)* enablement.

The *coordination perspective* is used for extracting the life cycles necessary for collaboratively enabling ecosystem capabilities. The collaboration coordination life-cycle phases include typically multi-lateral activities for making decisions about the structure, participants and characteristics of the collaboration. In the Pilarcos framework [2], [3] the collaboration coordination life cycle includes population of collaboration roles, multi-lateral negotiation about the characteristics of the collaboration participants and characteristics, enactment of the actual collaboration choreography, and collaboration dissolution, which we return to in Section IV. In the service delivery scenario, the coordination life cycles correspond to collaborative service engineering processes with phases such as service design, development and deployment.

The *compliance perspective* considers the life cycles necessary for monitoring the quality and conformance of actors with respect to ecosystem capabilities. The activities included in life cycles representing the compliance perspective of collaboration may include establishment of service-level agreements between ecosystem members, setting up necessary service-level monitoring infrastructures, and runtime monitoring of service activities. In the context of service delivery capability, the compliance life cycles may include activities for testing and certification of business services, for example.

The *dispensation perspective* addresses governance activities providing compensations due to unexpected behaviour of ecosystem members, and creating service quality feedback about the performance of business services and ecosystem members. With respect to the ecosystem capability of collaboration, a dispensation life cycle may trigger compensation processes in case of contract breaches. Reputation management [6] can be considered as a collaboration dispensation life cycle, which monitors the performance of collaboration actors and correspondingly provides reputation knowledge about the entities during collaboration dissolution.

Finally, the *enablement perspective* addresses governance activities that are required either for enabling the activities of other life cycles, or for guaranteeing some quality aspect of the ecosystem (e.g. privacy preservation). Enablement life cycles generally feed the ecosystem with knowledge artefacts required by other activities. Typical knowledge artefacts include new kinds of collaboration choreographies, and non-functional features available for addressing the quality aspects of service-based collaborations. Enablement life cycles related to ecosystem quality may include e.g. governance of trust, privacy and identity management.

We claim that the use of these four perspectives is necessary and sufficient for attaining improved correctness of collaborations.

C. Defining ecosystem life cycles

The service ecosystem life cycle is a cooperative process between ecosystem members for governing an ecosystem capability. As the participants of ecosystem life cycles are autonomous, the activities are enacted collaboratively. In this setting, a method for defining ecosystem life cycles must address especially issues related to collaborative decision making [7] and pragmatic interoperability [8].

For defining phases for the life cycles identified with governance perspectives, they are analyzed further from the viewpoint of collaborative decision making. We consider collaborative decision making as an activity, or a meta-process, comprising five different stages. These stages are *1)* expressing intention, *2)* preparation, *3)* commitment, *4)* operation, and *5)* dissolution. Applying these meta-process stages over the identified life cycles may induce zero or more life-cycle phases. The number and meaning of the phases induced depend on the problem domain, required granularity and design choices.

An ecosystem life cycle begins with one or more members expressing their intention to take action towards service capability governance. *Expressing intention* is a preliminary declaration about the willingness of an entity to participate in delivering an ecosystem capability. This stage is typically associated with activities related to ecosystem knowledge feeding, such as the publication of service offers.

In the *preparation stages*, activities are taken to establish necessary facilities for delivering the ecosystem capability. In particular, in this stage a coordinator for enacting the rest of the life cycle is selected, if such an actor is needed. Moreover, one or more communities are formed with their members comprising of entities that are responsible for enacting the rest of the life-cycle phases and activities. Towards this purpose, entities make assertions that inform others about their preparedness for action. In Pilarcos, the preparation stage involves business network population [2].

During the *commitment stage*, community members demonstrate their commitment to fulfilling their duties with respect to an ecosystem capability. Negotiation mechanisms can be used in this stage when pragmatic interoperability needs to be considered between potential collaborators [3]. Possible collaboration contracts are formed in commitment phases of collaboration establishment life cycles, for example. Multi-lateral negotiations are used for providing collaboration commitment in the Pilarcos framework [3].

In the *operation stage*, activities providing the ecosystem capability are enacted. Members of the community use directives and requests towards the ecosystem, each other, and their local domains for performing activities needed for discharging the obligations induced by their commitments. When considering collaboration capability, activities such as distributed workflow enactment and coordination, service monitoring, and breach management mechanisms [2] are of great importance.

Finally, during the *dissolution stage* of ecosystem life cycles, community members can perform activities to free their local resources, and provide declarations about the community and ecosystem members about their performance in the operation stage. In this stage of collaborative decision-making, the ecosystem is typically provided with e.g. reputation and service quality feedback.

The use of these five stages results in clearly defined protocols for the ecosystem.

III. The Pilarcos framework

The Pilarcos framework [2], [3] emphasizes the autonomy of business collaboration participants and business service interoperability. Interoperability and loose coupling is attained by utilizing Pilarcos infrastructure services, which provide facilities for metainformation management and sharing, service trading facilities for interoperable service delivery, dynamically negotiable collaboration establishment, and contract-based governance of business networks [2].

The Pilarcos framework considers inter-enterprise collaborations as *business networks* consisting of independently developed business services. A *business service* denotes a set of functionalities provided by an enterprise to its clientele and partners. It is governed by the enterprise's own business rules and policies, service-level agreements, as well as by business contracts and regulatory systems controlling the business area.

A business network is established dynamically to serve a certain business scenario or opportunity that is made public through a *business network model* (BNM) [2]. The business network model captures e.g. the roles and business processes (choreographies) that are relevant for the business scenario, and contains legally valid template contracts where the relevant parameters, such as participant identities, can be filled in during automated negotiations. Enterprises offer their business services for collaborations through *service offers* which compose a selection of inter-related business services for fulfilling the requirements of a business role.

The Pilarcos infrastructure services facilitate the sharing of engineering knowledge, service publication and discovery, collaboration establishment, eContracting, and trust and reputation management. The infrastructure services include [2]:

- services for establishing, modifying, monitoring, and terminating collaborations, or looking from the business service point of view, operations for joining and leaving a collaboration either voluntarily or by community decision, and leaving a persistent reputation trace about the success of the collaboration; and
- a set of knowledge repositories for storage of collaboration models, and ontologies of service types and business services to support interoperability validation.

The Pilarcos framework and the supporting infrastructure has been researched using a selection of methodologies. As a part of the constructive research methodology, Pilarcos infrastructure services have been implemented as a research prototype to gain experience on the feasibility of the studied approaches. Utilizing the prototype, performance measurements on the critical elements have been made to provide a basis for analytical models of the behaviour patterns of the system as a whole in order to reveal problem spots. The measurement results have been mainly published as student work or otherwise in Finnish.

In the daily working practices of the CINCO group, expertise from different domains of computer science and software engineering[4] is applied to studying potential problem points of the architecture, and scenarios important for the functionality and system quality, both from the perspective of autonomous participants and the ecosystem. In addition, the approaches taken are submitted for open criticism before industrial partners through TEKES (Finnish technology development centre) funded projects, which also has allowed us to study and address company use and threat scenarios. Architecture evaluation methodologies with similar focal points in expert analysis include e.g. ATAM [13].

The basic Pilarcos framework now supports collaboration and production life cycles that are further refined with aspects such as trust management, privacy-preservation and non-functional property governance. The next section elaborates on the collaboration and trust management life cycles.

IV. Evaluation

To demonstrate the usability of the systematic description methodology proposed in Section II, we utilize it on two ecosystem capabilities to produce example life cycles in the Pilarcos framework. The two targets are collaboration [2], representing core enabling ecosystem capability, and trust management [6], which represents a qualitative capability in the ecosystem. While the former affects collaborations and the latter is mainly internal to the enterprise, the capabilities overlap at private decision-making points that determine the member's continued participation in the collaboration: trust management is a prerequisite for collaboration establishment. Both ecosystem capabilities are considered from the coordination perspective in this paper. The collaboration capability corresponds with what is called the *eContracting life cycle* in Pilarcos. The trust management capability, in turn, binds into the flow of reputation knowledge through the ecosystem; this shared information acts as input to private decision-making.

A. Collaboration coordination

In Pilarcos, the establishment of a dynamic business network begins with entities publishing their service offers to the ecosystem, corresponding with the *expressing intention stage*. A service offer asserts that an ecosystem member can provide business service(s) that fulfil the obligations laid for a role in a business network model. Service offer publication thus makes explicit the intention of a service provider to take part in a certain business network model that describes a form of collaboration.

The *preparation phase* of the eContracting life cycle consists of population activities which produce a set of eContract proposals [3]. The ecosystem member initiating the collaboration selects a business network model from the BNM repository, fills it with preliminary constraints over participant properties and sends the BNM to an infrastructure service known as the populator [3]. The populator utilizes service offer repositories for discovering business services from the ecosystem that match the requirements laid by the BNM and the initiator. This includes addressing technical and semantic interoperability between selected services. After a successful population, each eContract proposal includes a set of interoperable service offers.

As we want to allow autonomic decisions about joining business networks and dynamic agreement about their properties, a commitment to join a business network must be established using mutual negotiations between the potential partners. In the *commitment phase* of the eContracting life cycle, the initiator chooses an eContract proposal produced by populator to be finalized using multi-lateral negotiations [3]. If the negotiations are successful, an eContract proposal is successfully filled in to produce an eContract that satisfies all participants. Negotiations are terminated without any commitments if a partner in the eContract proposal refuses to commit to the contract during the negotiations.

In the *operation phase* of the Pilarcos framework, the eContract is used for coordinating and monitoring the collaboration activities taking place between partners. Network management agents are responsible for the coordination and monitoring activities, while the business services provided by the entities take care of the business logic enactment [3].

Finally, the *dissolution phase* of the eContracting life cycle is entered when the eContract expires either successfully or by a major fault that cannot be dealt with. During the dissolution phase, the outcome of the operation phase is used as an input for updating reputation information in the ecosystem, although updates can also be sent out during the operation phase for longer collaborations. The reputation information is utilized during the population and negotiation phases for selecting appropriate partners into the business networks, as well as during the operation phase to identify potential changes in behaviour [6].

For defining ecosystem life cycles, a matrix representation can be used as a starting point. The Pilarcos collaboration coordination life cycle matrix representation is provided in Figure 1. The first column from the left describes the motive of the life cycle: the ecosystem capability in question and the governance perspective (see Section II-B) used in the analysis. In the life cycle described in Figure 1, the motive is "Collaboration coordination". The rows represent the five stages of collaborative decision making introduced in Section II-C. The "Life cycle phase" column identifies the life-cycle phases of the corresponding collaborative decision-making stages. The "Actor(s)" column denotes the actors taking part in the corresponding life-cycle phases. Input and output artefacts consumed and produced by corresponding phases are defined in the last two columns, respectively.

The matrix representation provides a description of

[4] Including e.g. formal methods for modelling complex systems [9], [10], model-driven engineering [11] and the ODP reference model's specification viewpoints and computational infrastructure model [12].

Motive	Goal	Life cycle phase	Actor(s)	Input(s)	Output(s)
Collaboration coordination	**Intention**	SOPublication	Service provider	N/A	Service offer
	Preparation	Population	Initiator; Populator; Service provider	BNM; Available services	eContract templates; Interoperable services
	Commitment	Negotiation	Initiator, Service provider	eContract templates; Interoperable services	eContract; Committed services
	Operation	Collaboration	Service provider	eContract; Committed services	Successful services; Failed services
	Dissolution	Dissolution	Service provider	eContract; Successful services; Failed services	Reputation information

Figure 1. Pilarcos collaboration coordination life cycle matrix representation.

ecosystem life-cycle actors and artefacts. The representation can be further formalized using an appropriate modelling language. The matrix representation of life-cycle actors and artefacts can be modelled e.g. as UML use case diagrams. The sequencing between life-cycle phases can be formalized with extended UML state machine diagrams; consequently, the processes, actors and artefacts related to ecosystem life cycles can be modelled using UML tools.

B. Trust management coordination

The life cycle corresponding to the coordination perspective of the trust management ecosystem life cycle in the Pilarcos framework is described in Figure 2. The resulting life cycle phases are described below.

The trust management (coordination) life cycle begins when a service provider selects the relevant reputation system or systems to connect into; this is represented by the *intention phase* (RSSelection) in Figure 2. There may be more than one reputation system available that is relevant for gaining experience information on the actors in the service ecosystem, with different policies of operation and costs of participation. One reputation network may focus on a specific field of business, for example, while another system may be more resistant against intentional spreading of misinformation [6]. A reputation system is a form of collaboration itself, governed by a reputation system contract. The reputation system contract determines the format, process and rules for sharing experience information in the reputation system, as well as sanctions for misinformation or omissions.

For the *preparation phase* (Configuration) of the trust management life cycle, the service provider configures its local trust decision and reputation update policies, and prepares to connect to the target reputation networks. This includes preparations for internally analysing the credibility of the information [6]. These preparations depend on the selected reputation systems; the chosen policies should be reasonably compatible with the reputation system contract. Major conflicts detected between the contract and local policies may lead to a need to return to the first phase and select another reputation system to join, as violating the reputation system contract may have adverse effects, such as a negative impact on the reputation of the service provider, or removal from the reputation system altogether.

In the *commitment phase* (RSJoin), the service provider joins the chosen reputation system(s), and signs the reputation system contract. This contract is not as negotiable as a regular collaboration contract, as the system contains a large and dynamic set of members; what is left is a choice of accepting or not accepting the contract as is, with possible minor selectable options. Depending on the reputation system, existing members may have a veto right to not allow the service provider to join the reputation system, for example due to earlier violations of the reputation system contract. The signed reputation system contract provides the service provider access to the reputation information shared through the system.

In the *operation phase*, the service provider makes semi-automated trust decisions based on the set trust management policies [6]; a human supervisor may make adjustments to the policies during the operational phase, if necessary. To support the trust decisions, the service provider utilizes reputation information from the reputation system as well as first-hand experiences from local monitors. The service

Motive	Goal	Life cycle phase	Actor(s)	Input(s)	Output(s)
Trust management coordination	**Intention**	RSSelection	Service provider	N/A	RS contract proposal
	Preparation	Configuration	Service provider	RS contract proposal	Trust policies
	Commitment	RSJoin	Service provider, RS members	RS contract proposal	RS contract
	Operation	Operation	Service provider, RS members	Trust policies; RS contract; Reputation information	Reputation information
	Dissolution	RSLeave	Service provider	RS contract	N/A

Figure 2. Pilarcos trust management coordination life cycle matrix representation.

provider also shares these first-hand experiences in the reputation system in accordance to the reputation system contract. Moreover, the service provider's own reputation may change in the reputation system, as other reputation system members submit experiences concerning it, and it may be able to rebut unfair experience reports.

In the *dissolution phase* (RSLeave), the service provider discharges itself from its reputation system membership. In essence, this life cycle can be seen to repeat itself for each reputation system the service provider joins; on the other hand, the changes in reputation system memberships are at most expected to happen when a new reputation system becomes relevant due to, for example, an extension of the service provider's interests into a new business domain. In essence, the major configuration steps are only done once for the entire service ecosystem, with minor refinements done as needed, and the dissolution phase is the equivalent of the service provider leaving the ecosystem.

C. Analysis

The description of these two selected life cycles illustrate the usage of the presented method, how life cycles intertwine in the ecosystem architecture, and how ecosystem artefacts are shared in the process. In this case, the core enabling capability of collaboration and the qualitative capability of trust management meet at the decision-making points in the collaborations. These two life cycles are considered from the coordination perspective, while other perspectives need similar considerations.

About the Pilarcos ecosystem framework we can observe three fundamental aspects. First, the systematic identification of life cycles (instead of using fixed enterprise architecture artefacts) enables dynamic changes on collaborations and services, and evolution of the ecosystem itself in terms of membership and recognised artefacts. Second, since the ecosystem knowledge base self-manages its internal consistency, the life cycles are forced to align with the ecosystem governing principles and to each other. Therefore, improved correctness properties for collaborations are attained. Third, the collaboration management mechanisms enable all stakeholders (i.e. clients, collaboration administrators, infrastructure service providers) to participate in the management processes, while they preserve their autonomy. This improves capabilities of refining collaborations to the specific needs in each case. The refinements can also be dynamic, as they are performed through life cycles.

About the ecosystem governance methodology we can observe that it provides sufficient guidelines for capturing the Pilarcos life cycles so that the collaboration management protocols and ecosystem knowledge base artefacts become addressed. Further, the correctness and consistency requirements identified for Pilarcos development in our earlier work [2], [3], [6], [7] are fully covered.

V. Conclusion

Current solutions for governing complex socio-technical systems, such as enterprise architecture frameworks (see e.g. [4]), are not feasible for managing service ecosystems in open and progressive business environments. Dynamism, autonomy and heterogeneity of the ecosystem and its members cannot be handled with approaches based on centralized decisions and control about the current and future state of the system. In this paper, we have proposed an approach for solving service ecosystem governance. The approach is based on identification of ecosystem capabilities and the definition of ecosystem life cycles for collaboratively governing the them. We described a method for life cycle identification and definition by using the Pilarcos framework [2], [3] as an example case.

We have identified six guiding principles for realizing service ecosystem governance:

1) identifying stakeholders and using strong identity management for ecosystem actors;
2) using collaboratively managed life cycles and choreographies;
3) explicitly declaring and controlling dependable actor behaviour;
4) addressing ecosystem knowledge management in all ecosystem operations;
5) ensuring that ecosystem governance activities can be aligned with and analyzed with respect to corporate, IT, EA and SOA governance principles and standards used in individual organizations; and
6) representing the ecosystem elements in a service ecosystem model.

We see predetermined roles, identities and identity management as essential for establishing loosely coupled service relationships between autonomous partners. Roles defined in collaboration choreographies and ecosystem life cycles provide means for declaring obligations and expectations for the behaviour of autonomous entities. Means for providing and certifying identities, and identity management are necessary for establishing trusted computing infrastructure.

In sustainable service ecosystems, the life cycles and choreographies are collaboratively managed and enacted. Such collaborative governance is needed especially for addressing pragmatic interoperability [8] concerns. In addition, participation in service ecosystems is enhanced by providing means for collaborative decision making [7].

In such a setting, the dependability of actor behaviour becomes an issue as well. Contracting, monitoring, trust management and dispensation procedures are some of the mechanisms that we see as important for supporting this kind of dependability and decreasing the risks involved in participating in ecosystem operations.

From our viewpoint, the knowledge management facilities provided by ecosystem infrastructure are essential for supporting ecosystem viability. Different kinds of knowledge are needed for supporting ecosystem operations: engineering knowledge for supporting global software engineering processes, interoperability knowledge providing means for dynamic collaboration establishment, and reputation information for trust management purposes are some examples of knowledge artefacts which need to be provided through a supporting management infrastructure.

Our methodology provides a systematic way of bringing together different governance principles and standards. The alignment of ecosystem governance activities with other governance principles requires that they are made explicit through a service ecosystem model, where ecosystem operations are modelled, their dependencies on the knowledge base specified, and the lack of conflicts between the different life cycles verified. This both allows ecosystem members to analyze the effects of the governance activities with respect to their local governance frameworks, and attains correctness and dependability for collaborations.

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