Supporting the Evolution of Research in Software Ecosystems: Reviewing the Empirical Literature

Konstantinos Manikas[(✉)]

Department of Computer Science, University of Copenhagen,
Copenhagen, Denmark
`kmanikas@di.ku.dk`

Abstract. The field of software ecosystems is gradually transiting towards an established means of software development and distribution, counting numerous areas of applicability. However, research in software ecosystems, although the activity of over 10 years, is still characterized as premature with significant lack of software ecosystem specific theories that are solid, mature, generic, and detailed enough to be measurable and transferable. In this study, we intent to come closer to an evolution of the field by supporting the "localization" of research, i.e. the focus on specific types of software ecosystems. To do so, we investigate the literature of empirical, non open source ecosystem studies and intent to identify the various aspects and perspectives studied.

In total, we review 56 empirical studies that investigate 55 software ecosystems. Our analysis confirms the assumption that proprietary software ecosystem studies lack deeper investigation of technical and collaborative aspects. Moreover, we identify an increased focus on organizational aspects and a rather limited focus on business. Furthermore, we identify common technology as the component investigated most in the ecosystems, both from the technical aspects, but also as means of applying orchestration. Finally, comparing the main areas with the overall ecosystem literature, we identify that empirical studies lack representation of health, motivation, actor activity, reusability, integration, and quality of ecosystems.

Keywords: Software ecosystems · Literature review · Empirical study review · Proprietary software ecosystems

1 Introduction

The field of software ecosystems has arguably moved from a new and upcoming field to an established means of developing and distributing software products, functions, or services. Currently, it is the most viable option of software product development in several domains and is counting examples in numerous other. Although the field has been active in research in the course of more than ten years, it can be argued that research is still scratching the surface of the field. The field can be characterized as one that is counting numerous and constantly

increasing studies that might go into depth in a specific aspect and/or type of software ecosystems, but find it challenging to make contributions that robust, while abstract enough to be applied to different types of ecosystems.

The case of software ecosystem *health* is a representative example of the evolution that theories in the field have been following. Software ecosystem health can be described as "the ability of the ecosystem to endure and remain variable and productive over time" [1]. It has been defined in the context of natural (biological) ecosystems and has appeared in software ecosystems mainly inspired by business ecosystems health[1]. Health, has been of focus and an important aspect from the early times of software ecosystem research [7], however the work on this aspect can be mainly characterized as either (a) too abstract, and thus not directly applicable (e.g. [1,8,9]), or (b) too specific, and thus challenging to be transfered to other (types of) ecosystems (e.g. [10–12]). Similar challenges can be noted in the *governance*[2] of software ecosystems [15–18].

This has as a result that, although theories and concepts evolve in the field, software ecosystems are still lacking a basic level of knowledge that is tailored to the specific needs of problems in the field. These theories are not solid and specific enough to allow for measurable results, while being abstract enough to allow for transferability (i.e. applied on ecosystems of different characteristics). This becomes magnified when taking into consideration the big variability in and differentiation of types of ecosystems existing.

This lack of specific theories is something that is also noted in the most recent and extensive systematic literature study of software ecosystems. [19] studies the literature of the field consisting of a total of 231 papers, spanning form 2007 to 2014. While examining the evolution of the field to characterize, among other, the field maturity, it is identified that the existing literature can be categorized as: **empirical but specific**, where one or more ecosystems are studied as means of addressing a problem, while the problem or the solution being highly coupled to these ecosystems; **temperature measuring**, where different theories, tools, or methods, usually imported from another field, investigate a problem that results in interpreting results based on assumptions. Furthermore, two steps for the evolution of research in the field towards its better maturity are proposed: (i) **research scoping**, where research should set more focus on defining the specific ecosystem parameters that study results are applicable, and (ii) **theory building**, where research should focus on defining theories that are designed for the specific characteristics and problems of software ecosystems. In order for (i) to be accelerated and have better results, some "ground-work" should be done on identifying and defining sets of parameters that separate the different types of ecosystems and their variability.

In this study, we intent to contribute towards an arguably higher level of maturity in the field by supporting work towards a better scoping of future research, as mentioned in (i). Our aim is to investigate the work studying

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[1] E.g. [2–6].

[2] An arguably more accurate term is *orchestration* [13,14] that better describes more "loose" organizational structures or ecosystems with voluntary contributions.

existing ecosystems and identify what aspects of (existing) software ecosystems are (empirically) studied. One of the most common differentiation of ecosystem types is the separation between ecosystems that are driven or supported by free and open source software (FOSS) and ecosystems that are driven or supported by proprietary software. Literature studying FOSS ecosystems, as identified by [7], tends to have deeper study of technical and collaborative aspects but might lack organizational and business perspectives. On the other hand, proprietary ecosystem studies tend to have do the opposite. In reality, the boarders of this polarization tend to be more obscure, as there are several ecosystems that support both FOSS and proprietary contributions or are based on both FOSS or proprietary common technologies.

In this study, we focus on proprietary ecosystems and intent to identify the various aspects and perspectives studied. More specifically, we review the empirical literature of proprietary software ecosystems, i.e. the literature of that studies some aspect(s) of an existing non-FOSS software ecosystem, to identify what ecosystem characteristics are defined. We do so, by reviewing 56 papers that study a total of 55 existing and non-FOSS software ecosystems. Our results reveal an increased focus in organizational aspects of software ecosystems, a restricted focus on business, with rather limited aspects of revenues and monetization. Moreover, our analysis confirms the view of proprietary ecosystem studies having limited access to proprietary information, such as source code, with a distinct lack of studies of the software perspectives of ecosystem contributions. The literature puts the most focus on the common technology both from the technical perspective but also as a means to apply orchestration to the ecosystem. Another main focus of the studies is the actors of the ecosystem and the relations among them. Finally, we compare the main areas of the empirical studies with the overall ecosystem literature and identify that ecosystem aspects such as health, motivation, actor activity, reusability, integration, and quality are not represented.

2 Related Work

The field of software ecosystems counts a number of secondary studies, but to our knowledge, none with primary focus on investigating the implications of empirical studies of existing software ecosystems. The systematic literature review of [7] identifies, among other, 42 software ecosystems in a literature body of 90 papers from 2007 to 2012. Manikas [19] expands this list to 108 for a literature body of 231 papers from 2007 to 2014.

In the context of secondary studies, Barbosa and Alves [20] conduct a mapping study of the literature of software ecosystems up to 2010 identifying 44 papers. Among their findings, they note that 10 studies were based on case studies. Santos et al. [21] combining the literature from that study and their previous study [22], identify four dimensions of software ecosystems: technical, business, social, and management - engineering. Hansen and Dybå [23] intent to build an overview of theories used in the literature. By reviewing a literature

body of 40 papers, they identify a set of theoretical areas while using the concept of "organizational ecology". Handoyo et al. [24] use the roles identified [7] and [20] to create a classification of ecosystem roles. Manikas and Hansen [1] focus on the context of health and review the literature of software ecosystem health and related areas. They find that software ecosystem health is heavily inspired from business ecosystems and propose a framework for the measurable definition of software ecosystem health. Fotrousi et al. [25] map the literature of software ecosystems to identify key performance indicators used in software ecosystems. They map 34 papers from software and digital ecosystems and identify right measurement attributes spread across seven entities. Franco-Bedoya et al [26] review part of the literature of open source software ecosystems (a total of 17 papers) to identify quality measures and provide input to their proposed quality model.

3   Method

In this study, we review the empirical literature of software ecosystems that is not build on a FOSS ecosystem, i.e. the academic literature that includes the study or investigation of an existing proprietary software ecosystem. This literature was identified as part of the analysis of the software ecosystem literature in the systematic literature study of [19]. This literature study was designed according to the guidelines of Kitchenham and Charters [27], using a similar protocol with the second most recent and extensive systematic literature study of software ecosystems [7]. This protocol includes the literature search in a list of academic libraries[3]. Moreover, the literature body was expanded with the papers from the International Workshop of Software Ecosystem (IWSECO) for years 2007-2004, the Workshop on Ecosystem Architectures (WEA) for years 2013-2014, the special issue on software ecosystems of the Journal of Systems and Software, and the special issue on software ecosystems of the Journal of Information Technology. All the identified literature contains the words "software ecosystem(s)" in either of the fields title, abstract, or keywords.

After we define the collected literature, we analyze it using the three structures of *"software ecosystem architecture"*, proposed by [28], and the ecosystem components, proposed by [29].

Christensen et al. in [28] investigate means of modeling software ecosystems where, based on the design of a software ecosystem, they propose the ecosystem analysis and modeling using the concept of software ecosystem architecture. This concept consists of three main structures that are necessary for the design and well-functioning of a software ecosystem:

Organizational structure. That covers aspects of the ecosystem related to the orchestration of the ecosystem elements, such as actor and software elements, as much as possible connections and interactions among these elements.

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[3] The digital libraries are: IEEE Explore, SpringerLink, ACM Digital Library, ScienceDirect, and Web of Science.

Business structure. That covers aspects of the ecosystem related to the creation of value. This is examined both from the perspective of the ecosystem, i.e. how is value added to the ecosystem, and the perspective of the ecosystem element, e.g. how is an actor gaining value from the contribution to the ecosystem.

Software structure. Covers aspects that relate to the software elements of the ecosystem, such as the structure of the common technology or the contributions to the ecosystem.

Moreover, in order to be specific and identify what elements of the ecosystems are studied, we use the approach of the ecosystem components. Knodel and Manikas in [29] propose a typification of software ecosystems challenging the existing ecosystems definitions. In this work they identify a number of components that ecosystems are consisted of[4]. They describe that an ecosystem is build on top of a **common technology**, that supports the interaction of a set of **actors**. The actors are part of the ecosystem by having an activity that results in one or several **contributions** to the ecosystem. The contributions can be of variable nature such as a (software) product or component, a service, or data (information). Each actor's activity in the ecosystem is motivated by one or several **incentives**. Moreover, the ecosystem exists and operates on a specific **environment**. The environment might include the domain of the ecosystem and the physical or digital aspects surrounding the ecosystem, while it can pose different requirements, or constraints to the ecosystem.

We use the three ecosystem structures and the five ecosystem components to analyze the ecosystem studies. Each study was analyzed and categorized according to what structure(s) it addresses and what are the main components investigated. One study can be categorized in more than one structure (e.g. both organizational and business) and have up to three components. The components classification was prioritized, e.g. a study can primarily focus on the common technology of an ecosystem with (secondary) focus on contributions.

4   Analysis

Our literature body includes 56 studies spanning from 2008 to 2014[5]. In total the literature studies 37 different, existing, named, software ecosystems and 18 anonymized.

Figure 1, shows how the papers are distributed in the three structures and what ecosystem components are the main focus for each structure. As it can be seen, the organizational structure has the largest focus with roughly 61 % of the total literature, while business has 37 %, and software 39 %[6].

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[4] In their work, they are mentioned as "ecosystem building blocks".
[5] The count of papers per year is 2008:2, 2009:2, 2010:6, 2011:7, 2012:6, 2013:11, 2014:22.
[6] One paper can be categorized in more than one structure.
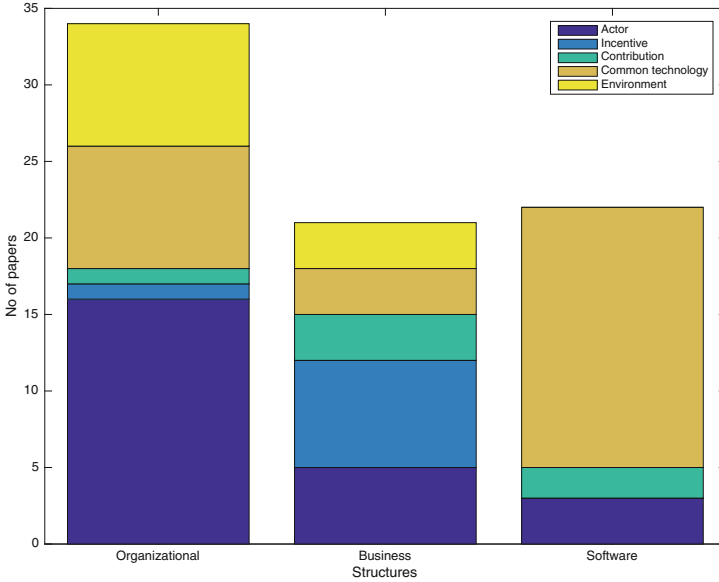
Fig. 1. Number of papers and ecosystem components according to ecosystem structures (Color figure online).

The most common component analyzed in the studies focusing on organizational structures is the 'actor', being the main focus of approximately 47 % of the studies within this structure. The most common second component appearing after actor in the organizational structure is 'incentive' and the third 'common technology'. This gives a good indication that many of the studies have been focusing on the network and relationships of actors and examining those from two main perspectives: the actor incentives and the common platform as means of facilitating actor relationship. In the business structure, it is not a surprise that the most common component is 'incentive' (33 % of the studies in the structure). As expected, the most common component that comes with 'incentive' is 'actor'. In the software structure, the most common component is 'common technology' (77 %) with most of those studies having 'contribution' as the second component.

If we examine the components independently from the architecture structures, we note that 'common technology' is the most common component[7]. Common technology usually has as a second component 'contribution' and that is mainly in the studies belonging to the software structure. These studies typically investigate the influence of software engineering aspects, such as software architecture, to the ecosystem. Another component that comes (to a less extent than the contribution) is 'environment'. These studies typically investigate the technical aspects of the common technology and how it poses additional restrictions,

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[7] The percentage distribution of components is common technology: 34 %, actor: 30 %, environment: 14 %, incentive: 13 %, and contribution: 9 %.

limitations, or specific rules to the ecosystem. The second most common component studied is 'actor'. Actor usually has a second component 'incentive' and, to a less extent, 'common technology'. What might come as a surprise in this context is the fact that contribution is not one of the most common components coming after actor. So there is not many studies[8] that investigate the actors and their contributions in this data set. This can be explained by two reasons: (i) the nature of the empirical sets, i.e. non-FOSS ecosystems, make it hard to study specific contributions in detail and (ii) the contribution component is in general not very studied (possibly also due to (i)).

Table 1 contains the identified main foci of the studies according to the ecosystem structures and components. Looking at the table, our first remark is that incentive and environment do not appear in the software structure. Moreover, the contribution component is not very studied in this structure. That, in combination with what is actually studied in the software structure, makes the statement of the nature of the ecosystems not allowing for deep analysis into contributions even stronger.

Examining the organizational structure, we note that actor, environment, and common technology are of focus. The representation of the common technology here provides the view of a common technology used as a means of imposing orchestration rules and strategies.

Looking at the business structure, we note a more spread distribution in the foci of components with the other two structures. This implies that different aspects of the business and value creation on software ecosystem are investigated. From the other side, it is notable that the central aspects of business, i.e. monetization and revenues, are arguably under-represented. While, intersection of business structures and organizational structure is more emphasized in the studies. This is also explained by the fact that many (52 %) of the business structure studies are also categorized as organizational structure.

Finally, when examining the focus areas of all the studies, we notice that there are several perspectives[9] that appear across components and structures. Furthermore, we notice that some of the ecosystem aspects that the literature has been focusing, including non-empirical literature, are not represented here. Comparing with the analysis of [19], that analyzes the literature and identifies trends, we note the following:

Organizational structure is lacking or is under-represented in studies of the aspects of *health*, and *actor activity*.

Business structure lacks focus on *motivation*, *process*, and *innovation*.

Software structure is focusing on the software architecture only in the level of the common technology (not contribution). Moreover, aspects like *reusability*, *evolution*, *integration*, and *quality* are not adequately represented.

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[8] Less than 4 % of the total.

[9] An example of this is the partnerships modeling/management/networks.

Table 1. Analysis of software ecosystem structures and components.

Category	Organizational	Business	Software
Actor	- Partnership model - Vendor modeling - Software supply network - Actor relationships - involvement - participation - Modeling co-innovation service systems - Concept building - Ecosystem characteristics - Inner source - Actor and software networks - Health - Actor (vendor - reseller) relationships - Network analysis - Collaboration models - Partner management [30–45]	- Vendor modeling - Software supply network - Actor (vendor - reseller) relationships - Partner management - Actor participation [31,32,40,43,45]	- Developer information needs - Inner source in small team organizations - Actor and software networks [37,38,46]
Incentive	- Partnership models [47]	- Partnership models - Business model analysis for new SECOs - Value chain models - Actor motivation - Business and value chain challenges - Revenue models - Actor incentive influence [47–53]	NA
Contribution	- Product requirement information flow [54]	- Multi-homing - User feedback [54–56]	- Variability modeling - Software implementation [57,58]
Common technology	- Software service supply chain model and architecture - Creating SECO for embedded software	- Architectural decisions - App Stores	- Architectural decisions - Software service supply chains

Table 1. (*Continued*)

Category	Organizational	Business	Software
	- Ecosystem establishment - App Stores - Cloud-based platform description - Ecosystem modeling - Multiple software product lines - Partnership impact in requirements engineering [59–66]	- SECO process [62,67,68]	- Software portability - Platform boundary resources - Infrastructure architecture - Variability issues - Ecosystem establishment - SECO process - Co-development in the cloud - Cloud-based platform description - Development and variability management - Evolution in industrial automation - Reverse engineering - Ecosystem modeling - Platform architecture - Multiple software product lines - Partnership impact in requirements [59,61,63–77]
Environment	- Ecosystem description - Ecosystem modeling - Strategic network (planning) - Collaboration and value creation challenges - Modeling ecosystems - Knowledge propagation - Ecosystem management - Governance framework [9,17,78–83]	- Strategic network (planning) - Collaboration and value creation challenges - Governance framework [17,80,81]	NA

5   Summary

In this study we review the empirical literature of existing proprietary (non-FOSS) software ecosystems to identify studied ecosystem aspects and perspectives. We identify a literature body of 56 empirical studies, studying a total of 55 software ecosystems. Our analysis includes the use of the concept of software ecosystem architecture and the three structures of software ecosystem modeling: organizational, business, and software structures. Moreover, we identify the main components studied in software ecosystem using the five ecosystem components: actor, incentive, common technology, contribution, and environment.

Our study confirms the assumption that proprietary software ecosystem studies lack deeper investigation of technical and collaborative aspects. Moreover, it reveals an increased focus on organizational structures and a rather limited focus on business with lack of revenue and monetization aspects. The most investigated ecosystem component is common technology, that is studied both as a technical but also as an orchestration element. Furthermore, actors, their incentives, and their influence to and from the common technology is also of focus in the studies. Finally, we compare the main areas of the empirical studies with the overall ecosystem literature and identify that ecosystem aspects such as health, motivation, actor activity, reusability, integration, and quality are not represented.

Appendix: Literature body

[9,17,30–83]

References

1. Manikas, K., Hansen, K.M.: Reviewing the health of software ecosystems-a conceptual framework proposal. In: Alves, C.F., Hanssen, G.K., Bosch, J., Jansen, S. (eds.) Proceedings of the 5th International Workshop on Software Ecosystems, Potsdam, Germany, June 11, 2013, vol. 987, pp. 33–44 (2013)
2. Iansiti, M., Levien, R.: Keystones and Dominators: Framing Operating and Technology Strategy in a Business Ecosystem. Harvard Business School, Boston (2004)
3. Iansiti, M., Richards, G.L.: The information technology ecosystem: structure, health, and performance. Antitrust Bull. **51**, 77 (2006)
4. Iansiti, M., Levien, R.: Strategy as ecology. Harvard Bus. Rev. **82**(3), 68–81 (2004)
5. Iansiti, M., Levien, R.: The Keystone Advantage: What the New Dynamics of Business Ecosystems Mean for Strategy, Innovation, and Sustainability. Harvard Business Press, Boston (2004)
6. den Hartigh, E., Tol, M., Visscher, W.: The health measurement of a business ecosystem. In: Proceedings of the European Network on Chaos and Complexity Research and Management Practice Meeting (2006)

7. Manikas, K., Hansen, K.M.: Software ecosystems-a systematic literature review. J. Syst. Softw. **86**(5), 1294–1306 (2013)
8. Hyrynsalmi, S., Seppänen, M., Nokkala, T., Suominen, A., Järvi, A.: Wealthy, healthy and/or happy—what does 'Ecosystem Health' stand for? In: Fernandes, J.M., Machado, R.J., Wnuk, K. (eds.) Software Business. LNBIP, vol. 210, pp. 272–287. Springer, Heidelberg (2015)
9. Berk, I.v.d., Jansen, S., Luinenburg, L.: Software ecosystems: a software ecosystem strategy assessment model. In: Proceedings of the Fourth European Conference on Software Architecture: Companion Volume, ECSA 2010, pp. 127–134. ACM, New York (2010)
10. Eckhardt, E., Kaats, E., Jansen, S., Alves, C.: The merits of a meritocracy in open source software ecosystems. In: Proceedings of the 2014 European Conference on Software Architecture Workshops, ECSAW 2014, pp. 7:1–7:6. ACM, New York (2014)
11. Jansen, S.: Measuring the health of open source software ecosystems: beyond the scope of project health. Inf. Softw. Technol. **56**(11), 1508–1519 (2014)
12. Lingen, S.V., Palomba, A., Lucassen, G.: On the software ecosystem health of open source content management systems. In: Alves, C.F., Hanssen, G.K., Bosch, J., Jansen, S. (eds.) Proceedings of the 5th International Workshop on Software Ecosystems, Potsdam, Germany, June 11, 2013, vol. 987, pp. 45–56. CEUR-WS.org (2013)
13. Jansen, S., Finkelstein, A., Brinkkemper, S.: A sense of community: a research agenda for software ecosystems. In: 31st International Conference on Software Engineering-Companion, ICSE-Companion 2009, vol. 2009, pp. 187–190, May 2009
14. Manikas, K.: Analyzing, Modelling, and Designing Software Ecosystems - Towards the Danish Telemedicine Software Ecosystem. Ph.D. thesis, University of Copenhagen (2015)
15. Albert, B., Santos, R., Werner, C.: Software ecosystems governance to enable it architecture based on software asset management. In: 2013 7th IEEE International Conference on Digital Ecosystems and Technologies (DEST), pp. 55–60, July 2013
16. Jansen, S., Cusumano, M.: Defining software ecosystems: a survey of software platforms and business network governance. In: Jansen, S., Bosch, J., Alves, C. (eds.) Proceedings of the Forth International Workshop on Software Ecosystems, Cambridge, MA, USA, June 18th, 2012, vol. 879, pp. 40–58. CEUR-WS.org (2012)
17. Wnuk, K., Manikas, K., Runeson, P., Lantz, M., Weijden, O., Munir, H.: Evaluating the governance model of hardware-dependent software ecosystems – a case study of the axis ecosystem. In: Lassenius, C., Smolander, K. (eds.) ICSOB 2014. LNBIP, vol. 182, pp. 212–226. Springer, Heidelberg (2014)
18. Manikas, K., Wnuk, K., Shollo, A.: Defining decision making strategies in software ecosystem governance. Technical report, Department of Computer Science, University of Copenhagen (2015)
19. Manikas, K.: Revisiting software ecosystems research: a longitudinal literature study. J. Syst. Softw. **117**, 84 (2016)
20. Barbosa, O., Alves, C.: A systematic mapping study on software ecosystems. In: Third International Workshop on Software Ecosystems (IWSECO-2011), pp. 15–26. CEUR-WS (2011)
21. Santos, R., Werner, C., Barbosa, O., Alves, C.: Software ecosystems: trends and impacts on software engineering. In: 2012 26th Brazilian Symposium on Software Engineering (SBES), pp. 206–210, Sept 2012

22. Santos, R.P., Werner, C.M.L.: A proposal for software ecosystem engineering. In: Third International Workshop on Software Ecosystems (IWSECO-2011), pp. 40–51. CEUR-WS (2011)

23. Hanssen, G.K., Dybå, T.: Theoretical foundations of software ecosystems. In: Jansen, S., Bosch, J., Alves, C. (eds.) Proceedings of the Forth International Workshop on Software Ecosystems, Cambridge, MA, USA, June 18th, 2012, vol. 879, pp. 6–17. CEUR-WS.org (2012)

24. Handoyo, E., Jansen, S., Brinkkemper, S.: Software ecosystem roles classification. In: Herzwurm, G., Margaria, T. (eds.) ICSOB 2013. LNBIP, vol. 150, pp. 212–216. Springer, Heidelberg (2013)

25. Fotrousi, F., Fricker, S.A., Fiedler, M., Le-Gall, F.: KPIs for software ecosystems: a systematic mapping study. In: Lassenius, C., Smolander, K. (eds.) ICSOB 2014. LNBIP, vol. 182, pp. 194–211. Springer, Heidelberg (2014)

26. Franco-Bedoya, O., Ameller, D., Costal, D., Franch, X.: Queso a quality model for open source software ecosystems. In: 2014 9th International Conference on Software Engineering and Applications (ICSOFT-EA), pp. 209–221, Aug 2014

27. Kitchenham, B., Charters, S.: Guidelines for performing systematic literature reviews in software engineering. Engineering 2(EBSE 2007–001) (2007)

28. Christensen, H.B., Hansen, K.M., Kyng, M., Manikas, K.: Analysis and design of software ecosystem architectures - towards the 4s telemedicine ecosystem. Inf. Softw. Technol. **56**(11), 1476–1492 (2014)

29. Knodel, J., Manikas, K.: Towards a typification of software ecosystems. In: Fernandes, J.M., Machado, R.J., Wnuk, K. (eds.) Software Business. LNBIP, vol. 210, pp. 60–65. Springer, Heidelberg (2015)

30. van Angeren, J., Jansen, S., Brinkkemper, S.: Exploring the relationship between partnership model participation and interfirm network structure: an analysis of the office365 ecosystem. In: Lassenius, C., Smolander, K. (eds.) ICSOB 2014. LNBIP, vol. 182, pp. 1–15. Springer, Heidelberg (2014)

31. Boucharas, V., Jansen, S., Brinkkemper, S.: Formalizing software ecosystem modeling. In: Proceedings of the 1st International Workshop on Open Component Ecosystems, IWOCE 2009, pp. 41–50. ACM, New York (2009)

32. Costa, G., Silva, F., Santos, R., Werner, C., Oliveira, T.: From applications to a software ecosystem platform: an exploratory study. In: Proceedings of the Fifth International Conference on Management of Emergent Digital EcoSystems, MEDES 2013, pp. 9–16. ACM, New York (2013)

33. Hilkert, D., Wolf, C.M., Benlian, A., Hess, T.: The "as-a-service"-paradigm and its implications for the software industry–insights from a comparative case study in CRM software ecosystems. In: Tyrväinen, P., Jansen, S., Cusumano, M.A. (eds.) ICSOB 2010. LNBIP, vol. 51, pp. 125–137. Springer, Heidelberg (2010). doi:10.1007/978-3-642-13633-7_11

34. Janner, T., Schroth, C., Schmid, B.: Modelling service systems for collaborative innovation in the enterprise software industry-the st. gallen media reference model applied. In: IEEE International Conference on Services Computing, SCC 2008, vol. 2, pp. 145–152, July 2008

35. Jansen, S., Brinkkemper, S., Finkelstein, A.: Business network management as a survival strategy: a tale of two software ecosystems. In: First International Workshop on Software Ecosystems (IWSECO-2009), pp. 34–48. Citeseer (2009)

36. Lettner, D., Angerer, F., Prähofer, H., Grünbacher, P.: A case study on software ecosystem characteristics in industrial automation software. In: Proceedings of the 2014 International Conference on Software and System Process, ICSSP 2014, pp. 40–49. ACM, New York (2014)

37. Linåker, J., Krantz, M., Höst, M.: On infrastructure for facilitation of inner source in small development teams. In: Jedlitschka, A., Kuvaja, P., Kuhrmann, M., Männistö, T., Münch, J., Raatikainen, M. (eds.) PROFES 2014. LNCS, vol. 8892, pp. 149–163. Springer, Heidelberg (2014)
38. Manikas, K., Hansen, K.M.: Characterizing the danish telemedicine ecosystem: making sense of actor relationships. In: Proceedings of the Fifth International Conference on Management of Emergent Digital EcoSystems, MEDES 2013, pp. 211–218 (2013)
39. Monteith, J.Y., McGregor, J.D., Ingram, J.E.: Proposed metrics on ecosystem health. In: Proceedings of the 2014 ACM International Workshop on Software-defined Ecosystems. BigSystem 2014, pp. 33–36. ACM, New York (2014)
40. Riis, P., Schubert, P.: Upgrading to a new version of an erp system: a multilevel analysis of influencing factors in a software ecosystem. In: 2012 45th Hawaii International Conference on System Science (HICSS), pp. 4709–4718, Jan 2012
41. Scholten, U., Fischer, R., Zirpins, C.: The dynamic network notation: harnessing network effects in paas-ecosystems. In: Proceedings of the Fourth Annual Workshop on Simplifying Complex Networks for Practitioners, SIMPLEX 2012, pp. 25–30. ACM, New York (2012)
42. Schultis, K.B., Elsner, C., Lohmann, D.: Architecture challenges for internal software ecosystems: a large-scale industry case study. In: Proceedings of the 22nd ACM SIGSOFT International Symposium on Foundations of Software Engineering, FSE 2014, pp. 542–552. ACM, New York (2014)
43. Schütz, S.W., Kude, T., Popp, K.M.: The impact of software-as-a-service on software ecosystems. In: Herzwurm, G., Margaria, T. (eds.) ICSOB 2013. LNBIP, vol. 150, pp. 130–140. Springer, Heidelberg (2013)
44. Molder, J., van Lier, B., Jansen, S.: Clopenness of systems: the interwoven nature of ecosystems. In: Third International Workshop on Software Ecosystems (IWSECO-2011), pp. 52–64. CEUR-WS (2011)
45. Wnuk, K., Runeson, P., Lantz, M., Weijden, O.: Bridges and barriers to hardware-dependent software ecosystem participation-a case study. Inf. Softw. Technol. **56**(11), 1493–1507 (2014)
46. Haenni, N., Lungu, M., Schwarz, N., Nierstrasz, O.: A quantitative analysis of developer information needs in software ecosystems. In: Proceedings of the 2014 European Conference on Software Architecture Workshops, ECSAW 2014, pp. 12:1–12:6. ACM, New York (2014)
47. Andresen, K., Brockmann, C., Drager, C.: A classification of ecosystems of enterprise system providers - an empirical analysis. In: 2013 46th Hawaii International Conference on System Sciences (HICSS), pp. 4034–4044, Jan 2013
48. Axelsson, J., Papatheocharous, E., Andersson, J.: Characteristics of software ecosystems for federated embedded systems: a case study. Inf. Softw. Technol. **56**(11), 1457–1475 (2014)
49. Handoyo, E., Jansen, S., Brinkkemper, S.: Software ecosystem modeling: the value chains. In: Proceedings of the Fifth International Conference on Management of Emergent Digital EcoSystems, MEDES 2013, pp. 17–24. ACM, New York (2013)
50. Howison, J., Herbsleb, J.D.: Incentives and integration in scientific software production. In: Proceedings of the 2013 Conference on Computer Supported Cooperative Work, CSCW 2013, pp. 459–470. ACM, New York (2013)
51. Olsson, H.H., Bosch, J.: Ecosystem-driven software development: a case study on the emergingchallenges in inter-organizational R&D. In: Lassenius, C., Smolander, K. (eds.) Software Business. Towards Continuous Value Delivery. LNBIP, vol. 182, pp. 16–26. Springer, Switzerland (2014)

52. Popp, K.M.: Hybrid revenue models of software companies and their relationship to hybrid business models. In: Third International Workshop on Software Ecosystems (IWSECO-2011), pp. 77–88. CEUR-WS (2011)
53. Ververs, E., van Bommel, R., Jansen, S.: Influences on developer participation in the debian software ecosystem. In: Proceedings of the International Conference on Management of Emergent Digital EcoSystems, MEDES 2011, pp. 89–93. ACM, New York (2011)
54. Knauss, E., Damian, D., Knauss, A., Borici, A.: Openness and requirements: opportunities and tradeoffs in software ecosystems. In: 2014 IEEE 22nd International Requirements Engineering Conference (RE), pp. 213–222, Aug 2014
55. Idu, A., van de Zande, T., Jansen, S.: Multi-homing in the apple ecosystem: why and how developers target multiple apple app. stores. In: Proceedings of the International Conference on Management of Emergent Digital EcoSystems, MEDES 2011, pp. 122–128. ACM, New York (2011)
56. Schneider, K., Meyer, S., Peters, M., Schliephacke, F., Mörschbach, J., Aguirre, L.: Feedback in context: supporting the evolution of IT-ecosystems. In: Ali Babar, M., Vierimaa, M., Oivo, M. (eds.) PROFES 2010. LNCS, vol. 6156, pp. 191–205. Springer, Heidelberg (2010). doi:10.1007/978-3-642-13792-1_16
57. Brummermann, H., Keunecke, M., Schmid, K.: Formalizing distributed evolution of variability in information system ecosystems. In: Proceedings of the Sixth International Workshop on Variability Modeling of Software-Intensive Systems, VaMoS 2012, pp. 11–19. ACM, New York (2012)
58. Keunecke, M., Brummermann, H., Schmid, K.: The feature pack approach: systematically managing implementations in software ecosystems. In: Proceedings of the Eighth International Workshop on Variability Modelling of Software-Intensive Systems, VaMoS 2014, pp. 20:1–20:7. ACM, New York (2013)
59. Aoyama, M.: Model and its management architecture of software service supply chains. In: Mochimaru, M., Ueda, K., Takenaka, T. (eds.) Serviceology for Services, pp. 181–189. Springer, Japan (2014)
60. Eklund, U., Bosch, J.: Introducing software ecosystems for mass-produced embedded systems. In: Cusumano, M.A., Iyer, B., Venkatraman, N. (eds.) ICSOB 2012. LNBIP, vol. 114, pp. 248–254. Springer, Heidelberg (2012)
61. Hanssen, G.K.: A longitudinal case study of an emerging software ecosystem: implications for practice and theory. J. Syst. Softw. **85**(7), 1455–1466 (2011)
62. Jansen, S., Bloemendal, E.: Defining app stores: the role of curated marketplaces in software ecosystems. In: Herzwurm, G., Margaria, T. (eds.) ICSOB 2013. LNBIP, vol. 150, pp. 195–206. Springer, Heidelberg (2013)
63. Kruize, J., Wolfert, S., Goense, D., Veenstra, T., Scholten, H., Beulens, A.: Integrating ICT applications for farm business collaboration processes using fi space. In: 2014 Annual SRII Global Conference (SRII), pp. 232–240, April 2014
64. McGregor, J.D.: A method for analyzing software product line ecosystems. In: Proceedings of the Fourth European Conference on Software Architecture: Companion Volume, ECSA 2010, pp. 73–80. ACM, New York (2010)
65. Urli, S., Blay-Fornarino, M., Collet, P., Mosser, S., Riveill, M.: Managing a software ecosystem using a multiple software product line: a case study on digital signage systems. In: 2014 40th EUROMICRO Conference on Software Engineering and Advanced Applications (SEAA), pp. 344–351, Aug 2014
66. Valenca, G., Alves, C., Heimann, V., Jansen, S., Brinkkemper, S.: Competition and collaboration in requirements engineering: a case study of an emerging software ecosystem. In: 2014 IEEE 22nd International Requirements Engineering Conference (RE), pp. 384–393, Aug 2014

67. Anvaari, M., Conradi, R., Jaccheri, L.: Architectural decision-making in enterprises: preliminary findings from an exploratory study in norwegian electricity industry. In: Drira, K. (ed.) ECSA 2013. LNCS, vol. 7957, pp. 162–175. Springer, Heidelberg (2013)

68. Järvinen, J., Huomo, T., Mikkonen, T., Tyrväinen, P.: From agile software development to mercury business. In: Lassenius, C., Smolander, K. (eds.) ICSOB 2014. LNBIP, vol. 182, pp. 58–71. Springer, Heidelberg (2014)

69. Bhowmik, T., Alves, V., Niu, N.: An exploratory case study on exploiting aspect orientation in mobile game porting. In: Bouabana-Tebibel, T., Rubin, S.H. (eds.) Integration of Reusable Systems. Advances in Intelligent Systems and Computing, vol. 263, pp. 241–261. Springer, Switzerland (2014)

70. Dal Bianco, V., Myllarniemi, V., Komssi, M., Raatikainen, M.: The role of platform boundary resources in software ecosystems: a case study. In: 2014 IEEE/IFIP Conference on Software Architecture (WICSA), pp. 11–20, April 2014

71. Bosch, J., Bosch-Sijtsema, P.: From integration to composition: on the impact of software product lines, global development and ecosystems. J. Syst. Softw. **83**(1), 67–76 (2010)

72. Brummermann, H., Keunecke, M., Schmid, K.: Variability issues in the evolution of information system ecosystems. In: Proceedings of the 5th Workshop on Variability Modeling of Software-Intensive Systems, VaMoS 2011, pp. 159–164. ACM, New York (2011)

73. Kourtesis, D., Bratanis, K., Bibikas, D., Paraskakis, I.: Software co-development in the era of cloud application platforms and ecosystems: the case of CAST. In: Camarinha-Matos, L.M., Xu, L., Afsarmanesh, H. (eds.) Collaborative Networks in the Internet of Services. IFIP AICT, vol. 380, pp. 196–204. Springer, Heidelberg (2012)

74. Lettner, D., Petruzelka, M., Rabiser, R., Angerer, F., Prähofer, H., Grünbacher, P.: Custom-developed vs. model-based configuration tools: experiences from an industrial automation ecosystem. In: Proceedings of the 17th International Software Product Line Conference Co-located Workshops, SPLC 2013 Workshops, pp. 52–58. ACM, New York (2013)

75. Lettner, D., Angerer, F., Grunbacher, P., Prahofer, H.: Software evolution in an industrial automation ecosystem: an exploratory study. In: 2014 40th EUROMICRO Conference on Software Engineering and Advanced Applications (SEAA), pp. 336–343, Aug 2014

76. Lungu, M.: Towards reverse engineering software ecosystems. In: IEEE International Conference on Software Maintenance, ICSM 2008, pp. 428–431 (2008)

77. Schultis, K.B., Elsner, C., Lohmann, D.: Moving towards industrial software ecosystems: are our software architectures fit for the future? In: 2013 4th International Workshop on Product Line Approaches in Software Engineering (PLEASE), pp. 9–12, May 2013

78. Alves, A.M., Pessôa, M.: Brazilian public software: beyond sharing. In: Proceedings of the International Conference on Management of Emergent Digital EcoSystems, MEDES 2010, pp. 73–80. ACM, New York (2010)

79. Bosch, J., Bosch-Sijtsema, P.: ESAO: a holistic ecosystem-driven analysis model. In: Lassenius, C., Smolander, K. (eds.) ICSOB 2014. LNBIP, vol. 182, pp. 179–193. Springer, Heidelberg (2014)

80. Nordström, H., Sääksjärvi, M.: Application service provisioning as a strategic network. In: Lamersdorf, W., Tschammer, V., Amarger, S. (eds.) Building the E-Service Society. IFIP, vol. 146, pp. 171–186. Springer, US (2004)

81. Pichlis, D., Raatikainen, M., Sevón, P., Hofemann, S., Myllärniemi, V., Komssi, M.: The challenges of joint solution planning: three software ecosystem cases. In: Jedlitschka, A., Kuvaja, P., Kuhrmann, M., Männistö, T., Münch, J., Raatikainen, M. (eds.) PROFES 2014. LNCS, vol. 8892, pp. 310–313. Springer, Heidelberg (2014)
82. van der Schuur, H., Jansen, S., Brinkkemper, S.: The power of propagation: on the role of software operation knowledge within software ecosystems. In: Proceedings of the International Conference on Management of Emergent Digital EcoSystems, MEDES 2011, pp. 76–84. ACM, New York (2011)
83. Viljainen, M., Kauppinen, M.: Software ecosystems: a set of management practices for platform integrators in the telecom industry. In: Regnell, B., van de Weerd, I., De Troyer, O. (eds.) ICSOB 2011. LNBIP, vol. 80, pp. 32–43. Springer, Heidelberg (2011)