Towards Living Inter-Organizational Processes

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***Abstract*—Business Process Management (BPM) has gained significant adoption in practice for enabling organizations to increase their effectiveness, efficiency, and flexibility. This broad adoption has not only been fostered by a rich and well-established theory to model, analyze, simulate, and enact business processes, but also by internationally accepted standards and mature technologies. Caused by the ever increasing speed and volatility of markets and the dynamics of new technologies, such as cloud infrastructures and mobile communications, we face a new generation of business processes, which we refer to as living inter-organizational processes. Such processes are not in control of one single organization; instead, they are enacted by multiple organizations, where no participating party possesses full control over the entire process. Such processes often involve a high number of actors that might even be unknown in advance. These actors require various degrees in participation, they are acting in heterogeneous environments. Moreover, such processes are often weakly structured or designed in an ad-hoc manner, and have to be continuously subject to evolution. Unfortunately, existing theories, methodologies, and technologies cannot cope with this challenging combination of aspects, which all have to be considered when dealing with living inter-organizational processes. The state of the art typically addresses singular aspects in isolation. However, a holistic approach to these challenges bears a tremendous potential. This paper aims to contribute towards a holistic approach to living inter-organizational processes. To this end, we describe different perspectives on inter-organizational processes and identify challenges for making them living processes.**

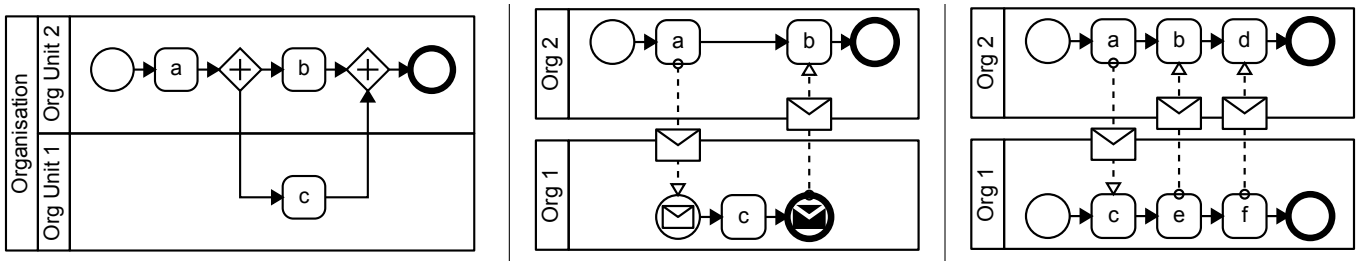
***Keywords*—inter-organizational processes; flexibility; correctness; traceability; scalability;**

I. Introduction

Business Process Management (BPM) is a field of computer science that provides methods, techniques, and tools to support the design, enactment, monitoring, and analysis of operational business processes [1], [2]. Business process models play an important role at different stages of BPM, for instance as a blueprint for design, a template for enactment, a benchmark for monitoring, or a schema of analysis. A process model typically defines the activities of a process, the data being processed, the parties being involved, and conditions of when certain paths are activated. On the technical level, the enactment of business processes is typically facilitated by Business Process Management Systems (BPMS), traditionally referred to as workflow systems. A BPMS uses a process model as a template for execution, at runtime populating data fields, allocating tasks to user, and keeping track of the state of each individual process instance. BPMS belong to the wider class of Process-aware Information Systems (PAIS), which support the execution of processes, but not necessarily require a process model to be explicitly defined [3].

BPMS and PAIS have been heavily adopted by industry for efficiently and effectively supporting the execution of their business processes. Most of these applications have been scoped within the bounds of a single enterprise. While processes often do not stop on the border of companies, the definition of executable processes within a company that has central control and complete transparency of the state of its process instances reduces the complexity of several management tasks. Research on BPM has made significant advancements on topics that can be tied to an intra-organizational context. For instance, it is well understood how control-flow properties like soundness can be checked efficiently before a process model is enacted on a BPMS [4]; how process mining can be conducted for log data stemming from a single information system [5]; how a process model can be changed without producing conflicts with running instances [6]; how resources can be scheduled efficiently [7]; how error and escalation situations can be identified [8]; how variants of a standardized process can be reused across departments [9]; and which infrastructure is required to deploy such processes in an efficient, manageable and scalable way [10].

The increase in complexity has hindered the adoption of BPM on an inter-organizational level. Several of the mentioned questions are significantly harder to address once we have no longer a central BPMS controlling the execution of a processes. When we use a BPMS to automate an intra-organizational business process, the state of this process is completely represented in the central BPMS throughout the entire life of a process instance. In case there is a coordinator, the state of a process instance is only partially represented in the BPMS, but the coordinator is aware at any stage which party has to return control and which parties would be to involve afterwards. In case of an inter-organizational process, there is not even a party who has a central role such as the coordinator. Both the coordinator processes and the choreography processes pose new challenges that warrant substantial extensions to existing intra-organizational concepts and techniques. These do not only relate to the lean specification and efficient implementation, but most importantly to the ongoing evolution across organizational boundaries. Based on these characteristics, we denote inter-organizational processes as living.



(a) One Organization, Central Control

(b) Multiple Organizations, Central Control

(c) Multiple Organizations, Peers, Distributed Control

Fig. 1: From Central Control of Internal Processes to Distributed Control of IOPs

This paper aims to contribute towards a holistic approach to living inter-organizational processes. To this end, we identify a variety of perspectives on inter-organizational living processes and their respective challenges. The remainder to the paper is structured accordingly. Section II classifies their perspectives in terms of distribution, behaviour, data, and resources. Section III describes challenges that systems supporting living inter-organizational processes have to consider.

II. Perspectives on Living Inter-Organizational Processes

This section describes inter-organizational processes from the perspectives of distribution, behaviour, data, and resources.

A. Distribution

BPMS have been heavily adopted for the support of processes in an intra-organizational setting, while central control and distributed control is less frequently utilized. Figure 1 illustrates the stages of loosened control of an example process. Figure 1a shows the case of central control that we typically encounter when we use a BPMS to automate intra-organizational business processes. The state of this process is completely represented in the BPMS throughout the entire life of a process instance. Figure 1b depicts the case of one party serving as a coordinator. In this case, the state of a process instance is only partially represented in the BPMS, but the coordinator is aware at any stage which party has to return control and which parties would be to involve afterwards. Figure 1c shows a choreography process. In this case, there is not necessarily a party that serves as the coordinator.

Both the coordinator processes and the choreography processes pose new challenges that warrant substantial extensions to existing intra-organizational concepts and techniques. Flexibility has to be approached in a much more careful way as the impact of local changes for distributed parts of the process might not be directly obvious. In the same regard, the checking of correctness needs to consider the interplay of various parties. Also, it becomes much more difficult to trace the overall process while potentially unknown parties conduct certain pieces of work. On the other hand, distribution offers the chance of better scalability as it might prevent the process from being dependent on a singular point of failure.

B. Behaviour

As the discussion of distribution reveals, not all parties have an overview of the behaviour of the process. Therefore, there are specific notations needed for describing the behaviour on an inter-organizational level. Dedicated languages have been defined for describing choreographies. The most prominent example is the choreography diagram, which is part of the BPMN 2.0 specification [11]. A choreography diagram expresses the order and conditions of message exchanges between several parties. Other important concepts are business protocols and mutual commitments as specified in [12]. Approaches for mapping inter-organizational processes to intra-organizational processes are discussed among others in [13] and [14].

C. Data

As inter-organizational processes might not have a party serving as a central control point, also the data can be distributed. This raises the question of transactional properties for these kinds of business processes. Workflow transactions relate to work on adapting transaction models from databases [15] to workflow systems [16], [17]. Beyond classical workflow data, inter-organizational processes increasingly rely on sensor data and contextual data. Often, this leads to an extensive amount of data that requires techniques such as complex event processing for identifying business-relevant patterns. Also, there is an increasing need for cross-organizational collaboration. This can entail sharing documents or jointly working on projects with people outside the own organization.

D. Resources

Classical workflow processes build on the assumption that responsibilities are pre-defined or at least pre-defined in terms of the set of potential resources. Inter-organizational processes involve both human and system resources. As the actions of resources outside one's own organization might not be directly observable, there are stronger needs for establishing trust and commitment. For these reasons, quality of service [18] and service-level agreements play an important role [19].

III. Challenges of Living Inter-Organizational Processes

This section describes important challenges of living inter-organizational processes. These include flexibility, correctness, traceability, and scalability. These have to be considered for

achieving flexible and seamless evolution as much as changeability while managing variability.

A. Flexibility

Flexible process support by a BPMS can be characterized by four major flexibility needs, namely support for variability, looseness, adaptation, and evolution [20]. Variability requires that processes have to be handled differently depending on the given context. Process variants typically share the same essential behaviour from which is deviated at stages. Variability might stem from differences in outputs, customers and regulations of a process [9]. Looseness refers to the fact that only a goal of a process might be known a priori. For instance, knowledge-intensive processes can be characterized non-repeatable, unpredictable, and emergent. Also the parameters determining the exact course of action are often not clear beforehand. For this reason, these processes cannot be fully pre-specified. Healthcare processes often show these characteristics [21]. Adaptation refers to the capability of a BPMS to adapt the process to emerging events. When such events occur, the process does not adequately reflect the real-world process anymore. Therefore, one or several process instances have to be adapted in order to realign the computerized processes with the real-world. Evolution refers to the ability of the BPMS to change process schemas when the real-world process evolves. Since business processes can change over time, it has to be ensured that real-world processes and the BPMS remain aligned. Technically, this requires propagating changes to the BPMS.

B. Correctness

Inter-organizational processes face challenges in terms of correctness. The concurrency of execution involving several parties and the partial visibility of the behaviour of the involved parties makes verification more difficult as for intra-organizational processes. Formal analysis techniques have been partially adapted to the level of inter-organizational processes, for instance [22], [23], but often the data perspective is not explicitly integrated. Beyond verification, correctness checking also requires techniques for validation, i.e. checking whether the inter-organizational process works according to the expected rules [2]. There is a need for testing strategies that sufficiently cover the spectrum of potential interactions and data instances. The interplay of changing processes and assuring their correctness is discussed for intra-organizational processes [24], while correctness of change on an inter-organizational level is hardly covered.

C. Traceability

Inter-organizational processes are more difficult to trace due to the distributed nature of execution. Therefore, there is a stronger need to monitor which progress is made at which point in time for which steps of the process. Making event data available between the different parties therefore plays an important role for traceability. The desirable visibility of state information can, for instance, be achieved based on making position data available, which stems from tracking events of GPS movements. Such data is highly important for monitoring whether agreed upon service levels are actually achieved. In an inter-organizational setting, event queries have to be specified, potentially using languages like BP-QL [25] or BPMN-Q [26], [27], building on formal languages such as ECL [28] or GEM [29]. On the other hand, the accessibility of shared data has to be balanced with privacy and security considerations. Therefore, mechanisms are needed for providing temporal access in a simple and efficient manner.

D. Scalability

Changes in process instances due to process evolution and adaptation, but also simply a higher or lower number of concurrent process instances in a volatile process landscape, make it necessary to support scalability [30]. Process steps may be resource-intensive, leading to ever-changing requirements regarding the computing resources needed to execute them. Hence, scalability is necessary to execute processes in a reliable way and adapt resources to changes ("change tolerance"). In order to achieve scalability, a BPMS needs to be able to lease and release computing resources, and provide the necessary forecasting, load balancing, and resource allocation mechanisms. Using Cloud technologies and especially virtualization, it is possible to allocate process steps to computing resources obtained on demand from Cloud platform providers. So far, only little research has been done in this area, either with a focus on single applications or services (e.g., [31], [32]), or Scientific Workflows (e.g., [33]). To the best of our knowledge, apart from the Vienna Platform for Elastic Processes (ViePEP) [34], there is no BPMS able to control a set of processes in a scalable way by making use of on demand self-service provided by Cloud providers. However, ViePEP only applies a very basic, rule-based resource forecasting and optimization approach. Furthermore, scalability also has to be provided on the analytical and the conceptual side. For instance, mining large-scale process-related event data requires dedicated approaches [35].

IV. Conclusion

In this paper we discussed different perspectives on inter-organizational processes, namely distribution, behaviour, data, and resources. Furthermore, we identified flexibility, correctness, traceability and scalability as challenges for achieving living inter-organizational processes. A lot of research has been conducted on these different aspects; however, often this research has focused on a singular perspective and a singular challenge, mostly in an intra-organizational context. A full research program is needed to study how different perspectives and challenges interrelate in an inter-organizational setting for making inter-organizational processes living.

References

[1] W. Aalst and K. Hee, *Workflow Management: Models, Methods, and Systems*. The MIT Press, 2002.

[2] M. Dumas, M. L. Rosa, J. Mendling, and H. A. Reijers, *Fundamentals of Business Process Management*. Springer, 2013.

[3] M. Dumas, A. Hofstede, and W. Aalst, Eds., *Process Aware Information Systems: Bridging People and Software Through Process Technology*. Wiley Publishing, 2005.

[4] M. Weske, *Business Process Management: Concepts, Languages, Architectures, Second Edition*. Springer-Verlag, 2012.

[5] W. M. P. van der Aalst, *Process Mining - Discovery, Conformance and Enhancement of Business Processes*. Springer, 2011.

[6] B. Weber, M. Reichert, and S. Rinderle-Ma, "Change patterns and change support features - enhancing flexibility in process-aware information systems," *Data Knowl. Eng.*, vol. 66, no. 3, pp. 438–466, 2008.

[7] J. Cardoso, A. P. Sheth, J. A. Miller, J. Arnold, and K. Kochut, "Quality of service for workflows and web service processes," *J. Web Sem.*, vol. 1, no. 3, pp. 281–308, 2004.

[8] W. M. P. van der Aalst, M. Rosemann, and M. Dumas, "Deadline-based escalation in process-aware information systems," *Decision Support Systems*, vol. 43, no. 2, pp. 492–511, 2007.

[9] A. Hallerbach, T. Bauer, and M. Reichert, "Capturing variability in business process models: the provop approach," *Journal of Software Maintenance*, vol. 22, no. 6-7, pp. 519–546, 2010.

[10] H. Li and S. Venugopal, "Using reinforcement learning for controlling an elastic web application hosting platform," in *ICAC*, H. Schmeck, W. Rosenstiel, T. F. Abdelzaher, and J. L. Hellerstein, Eds. ACM, 2011, pp. 205–208.

[11] Object Management Group, *Business Process Model and Notation (BPMN)*, version 2.0 ed., 2011.

[12] N. Desai, A. K. Chopra, and M. P. Singh, "Amoeba: A methodology for modeling and evolving cross-organizational business processes," *ACM Trans. Softw. Eng. Methodol.*, vol. 19, no. 2, 2009.

[13] W. M. P. van der Aalst and M. Weske, "The p2p approach to interorganizational workflows," in *CAiSE*, ser. Lecture Notes in Computer Science, K. R. Dittrich, A. Geppert, and M. C. Norrie, Eds., vol. 2068. Springer, 2001, pp. 140–156.

[14] J. Mendling and M. Hafner, "From ws-cdl choreography to bpel process orchestration," *J. Enterprise Inf. Management*, vol. 21, no. 5, pp. 525–542, 2008.

[15] H. Garcia-Molina and K. Salem, "Sagas," in *ACM SIGMOD Record*, vol. 16, no. 3. ACM, 1987, pp. 249–259.

[16] D. Georgakopoulos, M. F. Hornick, and A. P. Sheth, "An overview of workflow management: From process modeling to workflow automation infrastructure," *Distributed and Parallel Databases*, vol. 3, no. 2, pp. 119–153, 1995.

[17] G. Alonso, D. Agrawal, A. El Abbadi, M. Kamath, R. Günthör, and C. Mohan, "Advanced transaction models in workflow contexts," in *ICDE*, S. Y. W. Su, Ed. IEEE Computer Society, 1996, pp. 574–581.

[18] L. Zeng, B. Benatallah, A. H. H. Ngu, M. Dumas, J. Kalagnanam, and H. Chang, "Qos-aware middleware for web services composition," *IEEE Trans. Software Eng.*, vol. 30, no. 5, pp. 311–327, 2004.

[19] A. Keller and H. Ludwig, "The wsla framework: Specifying and monitoring service level agreements for web services," *Journal of Network and Systems Management*, vol. 11, no. 1, pp. 57–81, 2003.

[20] M. Reichert and B. Weber, *Enabling Flexibility in Process-Aware Information Systems - Challenges, Methods, Technologies*. Springer, 2012.

[21] R. Lenz and M. Reichert, "It support for healthcare processes - premises, challenges, perspectives," *Data Knowl. Eng.*, vol. 61, no. 1, pp. 39–58, 2007.

[22] C. Ouyang, M. Dumas, W. M. P. van der Aalst, A. H. M. ter Hofstede, and J. Mendling, "From business process models to process-oriented software systems," *ACM Trans. Softw. Eng. Methodol.*, vol. 19, no. 1, 2009.

[23] N. Lohmann and K. Wolf, "Compact representations and efficient algorithms for operating guidelines," *Fundam. Inform.*, vol. 108, no. 1-2, pp. 43–62, 2011.

[24] S. Rinderle, M. Reichert, and P. Dadam, "Correctness criteria for dynamic changes in workflow systems - a survey," *Data Knowl. Eng.*, vol. 50, no. 1, pp. 9–34, 2004.

[25] C. Beeri, A. Eyal, S. Kamenkovich, and T. Milo, "Querying business processes with bp-ql," *Inf. Syst.*, vol. 33, no. 6, pp. 477–507, 2008.

[26] A. Awad, G. Decker, and M. Weske, "Efficient compliance checking using bpmn-q and temporal logic," in *BPM*, ser. Lecture Notes in Computer Science, M. Dumas, M. Reichert, and M.-C. Shan, Eds., vol. 5240. Springer, 2008, pp. 326–341.

[27] A. Awad and S. Sakr, "On efficient processing of bpmn-q queries," *Computers in Industry*, vol. 63, no. 9, pp. 867–881, 2012.

[28] C. Sánchez, S. Sankaranarayanan, H. Sipma, T. Zhang, D. L. Dill, and Z. Manna, "Event correlation: Language and semantics," in *EMSOFT*, ser. Lecture Notes in Computer Science, R. Alur and I. Lee, Eds., vol. 2855. Springer, 2003, pp. 323–339.

[29] M. Mansouri-Samani and M. Sloman, "Gem: a generalized event monitoring language for distributed systems," *Distributed Systems Engineering*, vol. 4, no. 2, pp. 96–108, 1997.

[30] S. Dustdar, Y. Guo, B. Satzger, and H. L. Truong, "Principles of Elastic Processes," *IEEE Internet Computing*, vol. 15, no. 5, pp. 66–71, 2011.

[31] R. Buyya, R. Ranjan, and R. N. Calheiros, "InterCloud: Utility-Oriented Federation of Cloud Computing Environments for Scaling of Application Services," in *10th International Conference on Algorithms and Architectures for Parallel Processing (ICA3PP 2010)*, ser. Lecture Notes in Computer Science, vol. 6081. Springer, Berlin Heidelberg, 2010, pp. 13–31.

[32] U. Lampe, T. Mayer, J. Hiemer, D. Schuller, and R. Steinmetz, "Enabling Cost-Efficient Software Service Distribution in Infrastructure Clouds at Run Time," in *4th IEEE International Conference on Service-Oriented Computing and Applications (SOCA 2011)*. IEEE Computer Society, Washington, DC, USA, 2011, pp. 1–8.

[33] G. Juve and E. Deelman, "Scientific Workflows and Clouds," *ACM Crossroads*, vol. 16, no. 3, pp. 14–18, 2010.

[34] P. Hoenisch, S. Schulte, S. Dustdar, and S. Venugopal, "Self-Adaptive Resource Allocation for Elastic Process Execution (accepted for publication)," in *IEEE 6th International Conference on Cloud Computing (CLOUD 2013)*. IEEE Computer Society, Washington, DC, USA, 2013.

[35] K. Gerke, A. Claus, and J. Mendling, "Process mining of rfid-based supply chains," in *CEC*, B. Hofreiter and H. Werthner, Eds. IEEE Computer Society, 2009, pp. 285–292.