Decision Case Management for Digital Enterprise Architectures with the Internet of Things

Alfred Zimmermann, Rainer Schmidt, Dierk Jugel, Kurt Sandkuhl, Christian Schweda, Michael Möhring and Justus Bogner

Abstract The Internet of Things (IoT), Enterprise Social Networks, Adaptive Case Management, Mobility systems, Analytics for Big Data, and Cloud services environments are emerging to support smart connected products and services and the digital transformation. Biological metaphors of living and adaptable ecosystems with service-oriented enterprise architectures provide the foundation for self-optimizing and resilient run-time environments for intelligent business services and related distributed information systems. We are investigating mechanisms for flexible adaptation and evolution for the next digital enterprise architecture systems in the context of the digital transformation. Our aim is to support flexibility and agile transformation for both business and related enterprise systems through adaptation and dynamical evolution of digital enterprise architectures. The present research paper investigates mechanisms for decision case management in the context of multi-perspective explorations of enterprise services and Internet of Things architectures by extending original enterprise architecture reference models with state of art elements for architectural engineering for the digitization and architectural decision support.

Keywords Decision support • Decision case management • Internet of Things • Adaptive enterprise architecture • Digital transformation

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A. Zimmermann (✉) · D. Jugel · C. Schweda · J. Bogner
Herman Hollerith Center, Reutlingen University, Reutlingen, Germany
e-mail: alfred.zimmermann@reutlingen-university.de

R. Schmidt · M. Möhring
Munich University of Applied Sciences, Munich, Germany
e-mail: Rainer.Schmidt@hm.edu

M. Möhring
e-mail: michael.burch@visus.uni-stuttgart.de

D. Jugel · K. Sandkuhl
University of Rostock, Rostock, Germany

J. Bogner
Hewlett Packard Enterprise, Böblingen, Germany

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1 Introduction

Information, data and knowledge are fundamental concepts of our everyday activities. Social networks, smart portable devices, and intelligent cars, represent only a few instances of a pervasive, information-driven vision [25] for the next wave of the digital economy and the digital transformation. Digitization is the collaboration of human beings and autonomous objects beyond their local context using digital technologies. Digitization further increases the importance of information, data and knowledge as fundamental concepts of our everyday activities. By exchanging information human beings and intelligent objects are able to make decisions in a broader context and with higher quality.

Smart connected products and services expand physical components from their traditional core by adding information and connectivity services using the Internet. Internet of Things covers often-small intelligent physical components, which are connected over the Internet. Smart products and services amplify the basic value and capabilities and offer exponentially expanding opportunities [2]. Smart connected products combine three fundamental elements: physical components, smart components, and connectivity components. A challenging example of digital transformation for smart products results from the capabilities of the Internet of Things (IoT) [33]. Major trends for the digital transformation of digitized products and services are investigated in [10]. The Internet of Things enables a large number of physical devices to connect each other to perform wireless data communication and interaction using the Internet as a global communication environment.

The technological and business architectural impact of digitization has multiple aspects, which directly affect adaptable digital enterprise architectures and their related systems. Enterprise Architecture Management [19, 38] for Services Computing is the approach of choice to organize, build and utilize distributed capabilities for Digital Transformation [1, 25]. They provide flexibility and agility in business and IT systems. The development of such applications integrates the Internet of Things, Web and REST Services, Cloud Computing and Big Data management, among other frameworks and methods, like software architecture [3] and architectural semantic support.

Our current research paper focuses on the following research questions:

RQ1: What is the architectural decision context from Internet of Things architecture for the digital transformation of products and services?
RQ2: How digital enterprise architecture management should be holistically tailored to include Internet of Things architectures as the decisional context for architectural analytics and optimization efforts?
RQ3: How can collaborative decision support mechanisms be specifically designed by introducing decision case management models for digital enterprise architecture?

The following Sect. 2 sets the fundamental architectural context for Digital Transformation with the Internet of Things approach. Section 3 describes our research platform for digital enterprise architecture, which was extended by concepts from adaptive case management, architectural adaptation mechanisms and a specific model integration method. Section 4 presents our collaborative architectural engineering and transformation approach and links it with specific decisional and prediction mechanisms. Finally, we summarize in Sect. 5 our research findings and limitations, our ongoing work in academic and practical environments and our future research plans.

2 Architecting the Internet of Things

The Internet of Things maps and integrates real world objects into the virtual world, and extends the interaction with mobility systems, collaboration support systems, and systems and services for big data and cloud environments. Sensors, actuators, devices as well as humans and software agents interact and communicate data to implement specific tasks or more sophisticated business or technical processes. Therefore, smart products as well as their production are supported by the Internet of Things and can help enterprises to create more customer-oriented products. Furthermore, the Internet of Things is an important influence factor of the potential use of Industry 4.0 [28].

The Internet of Things (IoT) fundamentally revolutionizes today's digital strategies with disruptive business operating models [26], and holistic governance models for business and IT [34], in context of current fast changing markets [33]. With the huge diversity of Internet of Things technologies and products organizations have to leverage and extend previous enterprise architecture efforts to enable business value by integrating the Internet of Things into their classic business and computational environments.

The Internet of Things is the result of a convergence of visions [2, 10] like, a Things-oriented vision, an Internet-oriented vision, and a Semantic-oriented vision. The Internet of Things supports many connected physical devices over the Internet as a global communication platform. A cloud centric vision for architectural thinking of a ubiquitous sensing environment is provided by [10]. The typical configuration of the Internet of Things includes besides many communicating devices a cloud-based server architecture, which is required to interact and perform remote data management and calculations. A main question of current and further research is, how the Internet of Things architecture fits in a context of a services-based enterprise-computing environment? A service-oriented integration approach for the Internet of Things was elaborated in [29]. A layered Reference Architecture for the Internet of Things is proposed in [36] and (Fig. 1). Layers can be instantiated by suitable technologies for the Internet of Things.

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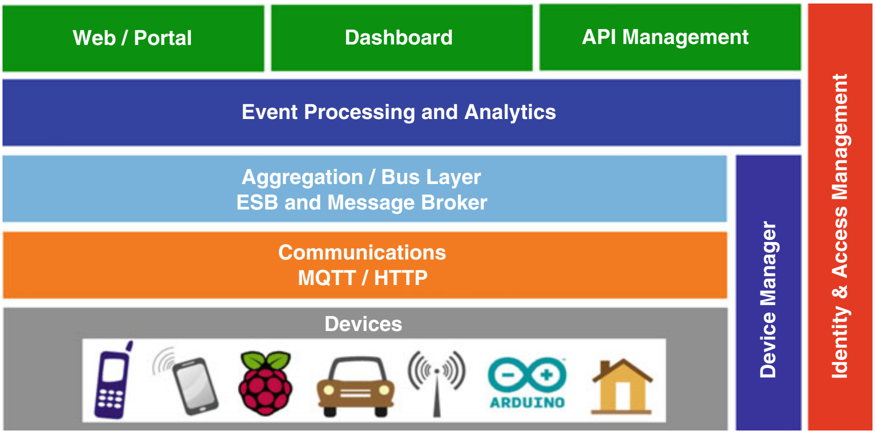

Fig. 1 Internet of Things reference architecture [36]

data to implement specific tasks or more sophisticated business or technical processes.

The Internet of Things architecture has to support a set of generic as well as some specific requirements. Generic requirements result from the inherent connection of a magnitude of devices via the Internet, often having to cross firewalls and other obstacles. Having to consider so many and a dynamic growing number of devices we need an architecture for scalability. Because these devices should be active in a 24 × 7 timeframe we need a high-availability approach [9], with deployment and auto-switching across cooperating datacenters in case of disasters and high scalable processing demands. Additionally, an Internet of Thing architecture has to support automatic managed updates and remotely managed devices. Often connected devices collect and analyze personal or security relevant data. Therefore, it is mandatory to support identity management, access control and security management on different levels: from the connected devices through the holistic controlled environment.

An inspiring approach for the development for the Internet of Things environments is presented in [24]. This research has a close link to our work about leveraging the integration of the Internet of Things into a decision framework for digital enterprise architectures. The main contribution considers a role-specific development methodology, and a development framework for the Internet of Things. The development framework contains a set of modeling languages for a vocabulary language to describe domain-specific features of an IoT application, an architecture language for describing application-specific functionality, and a deployment language for deployment features. Associated with this language set are suitable automation techniques for code generation, and linking to reduce the effort for developing and operating device-specific code. The metamodel for Internet of Things applications defines elements of an Internet of Things architectural reference model like, IoT resources of type: sensor, actuator, storage, and user interface.

3 Digital Enterprise Architecture

Enterprise Architecture Management (EAM) [19, 4] defines today with frameworks, standards [22, 23], tools and practical expertise a quite large set of different views and perspectives. We argue in this paper that a new refocused digital enterprise architecture approach should support digitization of products and services, and should be both holistic [37] and easily adaptable [38] to support IoT [39] and the digital transformation with new business models and technologies like social software, big data, services and cloud computing, mobility platforms and systems, security systems, and semantics support.

In this paper we extend our service-oriented enterprise architecture reference model for the context of managed adaptive cases and decisions [30], which are supported by case services of a collaborative case framework. Additionally, we have extended our architectural metamodel integration approach [39] to support enterprise architectures for digital transformations and the integration of Internet of Things.

ESARC—Enterprise Services Architecture Reference Cube [38] (Fig. 2) is an architectural reference model for an extended view on evolved digital enterprise architectures. ESARC is more specific than existing architectural standards of EAM—Enterprise Architecture Management [22, 23] and extends these architectural standards for digital enterprise architectures with services and cloud computing. ESARC provides a holistic classification model with eight integral architectural domains. These architectural domains cover specific architectural viewpoint descriptions [7] in accordance to the orthogonal dimensions of both architectural layers and architectural aspects [37, 38]. ESARC abstracts from a concrete business scenario or technologies, but it is applicable for concrete architectural instantiations to support digital transformations. The Open Group Architecture Framework [22]

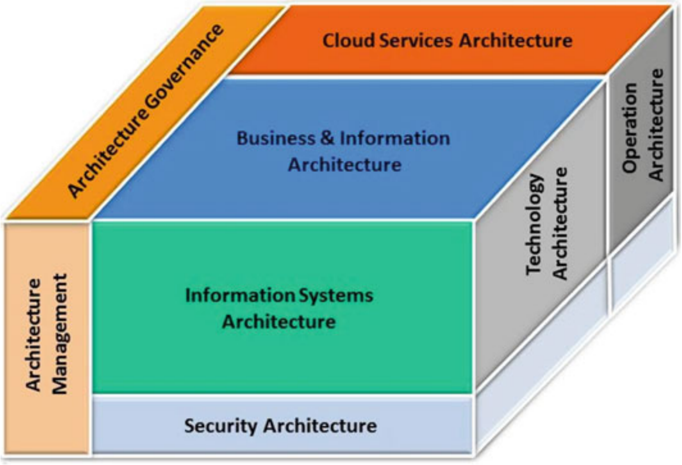

Fig. 2 Enterprise services architecture reference cube [37, 38]

provides the basic blueprint and structure for our extended service-oriented enterprise architecture domains.

Our research in progress main question asks, how we can dynamically federate these EA-IoT-Mini-Descriptions to a global high scalable EA model and information base by promoting a mixed automatic and collaborative decision process [15–17, 27]. For the automatic part we currently extend model federation and transformation approaches from [8] and [32] by introducing sematic-supported architectural representations, e.g. by using partial and federated ontologies and ontology-supported model transformations as well as associated mapping rules—as universal enterprise architectural knowledge representation, which are combined with special inference mechanisms.

Adaptation drives the survival [31] of digital enterprise architectures [38], platforms and application ecosystems. Volatile technologies and markets typically drive the evolution of ecosystems. The alignment of Architecture-Governance [34, 26] shapes resiliency, scalability and composability of components and services for distributed information systems.

4 Decision Case Management

A Decision Support System (DSS) is a system "to help improve the effectiveness of managerial decision making in semi-structured tasks" [18, p. 255]. In particular, knowledge intensive management activities, like Enterprise Architecture Management (EAM), can benefit from a DSS to improve architectural decision-making. We are exploring in our current research, how an enterprise architecture cockpit [15–17] can be leveraged and extended to a DSS for EAM. A cockpit presents a facility or device via which multiple viewpoints on the system under consideration can be consulted simultaneously. Each stakeholder who takes place in a cockpit meeting can utilize a viewpoint that displays the relevant information. Thereby, the stakeholders can leverage views that fit the particular role like Application Architect, Business Process Owner or Infrastructure Architect [35]. The viewpoints applied simultaneously are linked to each other such that the impact of a change performed in one view can be visualized in other views as well. Figure 3 gives the

Fig. 3 Example: enterprise architecture cockpit [16, 17]

idea of multi-perspectives of a collaborative enterprise architecture cockpit and social-based processes [27].

Jugel et al. [16] present a collaborative approach for decision-making for EA management. They identify decision making in such complex environment as a knowledge-intensive process strongly depends on the participating stakeholders. Therefore, the collaborative approach presented is built based on the methods and techniques of adaptive case management (ACM), as defined in [30].

The Case Management Modeling Notation (CMMN) [20] is a notation for ACM that describes mandatory and optional tasks (DiscretionaryItem), and thereby supports flexible processes. In line with Jugel et al. [17], we utilize CMMN to describe a collaborative decision-making case for EAM, cf. Fig. 4.

The *Issue* is the starting point of a collaborative decision-making case. This issue describes the problem space of the decision-making activity, which aligns with the perspective of Mayring [13]. We further assume that goals and success criterions, as required by Johnson et al. [14], have already been defined as part of strategic management activities. The issue is the reason why the EA has to be analyzed and decided upon. Based on this issue, involved stakeholders choose architectural viewpoints [7] that they need to analyze the issue.

The *decision-making step* [21] is the central activity of the decision-making case, as presented in Fig. 4. This step can involve different optional activities in which different kinds of quantitative and qualitative analysis techniques [5, 6] are applied:

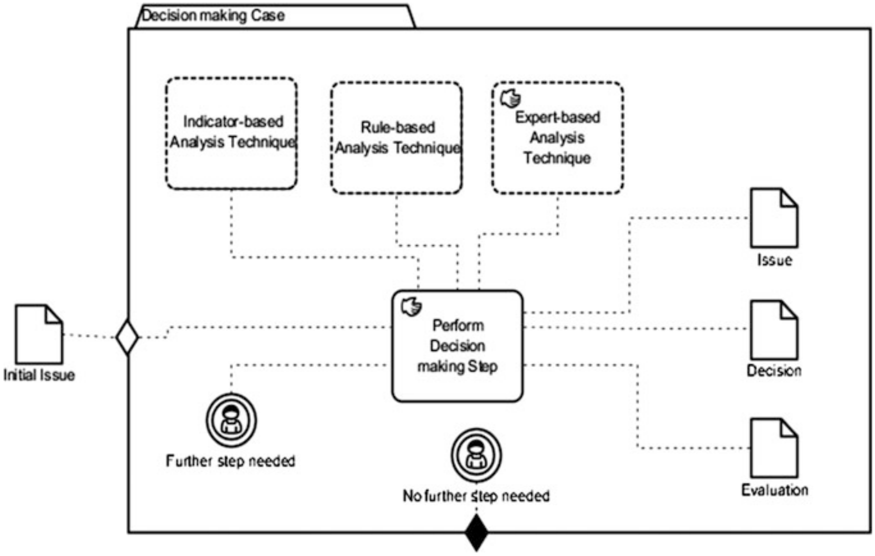

Fig. 4 CMMN model of a collaborative decision making case [17]

- *Expert-based analysis* techniques are dependent on expert knowledge and tacit information of the involved stakeholders. Jugel et al. [16] identify these techniques with interactive functions like “graphical highlighting and filtering”.
- *Rule-based analysis* techniques [11] correspond to algorithms that are used to identify patterns in the EA.
- *Indicator-based analysis* techniques [12] are formal methods that compute indicators from properties of the EA.

The *decision-making step* is based on case data consisting of an EA model and additional insights elicited in previous steps. Consequently, the insights gained during each step contribute to the *case file* (CaseFile) of the decision-making case. Derived values, like the values of KPIs are thereby not considered additional information, but only a different way of representing and aggregating existing information. Stakeholder decisions represent new information, which is added to the case file.

5 Conclusion

We have identified in this paper the need for an integral understanding and support of collaborative decisions in the process of architectural adaptation and enterprise transformation. According to our research questions we have leveraged a new model of extended digital enterprise architecture, which is well suited for adaptive models and transformation mechanisms. We have extended the previous more static defined basic enterprise reference architecture by new metamodel elements for supporting cooperative decisions using mechanisms from adaptive case management.

Related to our second research question we have presented our approach for collaborative processes in architectural engineering and transformation endeavors. We have additionally combined architectural engineering and transformation processes with elements from adaptive case management. We have extended typical architectural engineering processes with elements from social production, collective decision-making, value co-production, and week ties. Adaptive case management offers a lightweight model for knowledge-intensive processes.

We have finally merged architectural viewpoints with user decision-making processes within cooperative distributed environments for enterprise architecture management. We have introduced suitable individual decision support models and embedded them into cooperative analysis and engineering environments. We are currently working on extended decision support mechanisms for an architectural cockpit for digital enterprise architectures and related engineering processes. Additionally, we are currently considering elements from semantic-supported collaborative systems.

We have contributed to the current IS literature by introducing this new perspective for decision support in the context of digital enterprise architectures with

IoT. EA managers can benefit from new knowledge about adaptable enterprise architectures and can use it for decision support and can therefore reduce operational risks. Some limitations (e.g. use and adoption in different sectors, or the IoT integration technologies) must be considered. There is a need to integrate more analytics based decisions support and context-data driven architectural decision-making. By considering the context of service-oriented enterprise architecture, we have set the foundation for integrating metamodels and related ontologies for orthogonal architecture domains of our integrated Enterprise Architecture Management approach for the Internet of Things. Our results can help practical users to understand the integration of EAM with the Internet of Things and to support architectural decisions. Limitations can be found e.g. in the field of practical multi-level evaluation of our approach as well as domain-specific adoptions.

Future work will extend both mechanisms for adaptation and flexible integration of digital enterprise architectures as well as will extend decisional processes by rationales and explanations. Future work will also include conceptual work to federate EA-IoT-Mini-Descriptions to a global EA model and enterprise architecture repository by promoting a semi-automatic and collaborative decision process. We are currently extending our architectural model federation and transformation approaches with basic research for ontology-based model transformations and elements from related work. We are researching about semantic-supported architectural representations, as universal enterprise architectural knowledge representations, which are combined with special inference mechanisms. Additional improvement opportunities will focus on methods for visualization of architecture artifacts and control information to be operable in a multi-perspective architecture management cockpit.

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