On the Changing Role of Enterprise Architecture in Decentralized Environments: State of the Art

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***Abstract*—The decentralization of organizations and subsequent change to their management and operation style requires major changes in organization processes and heavily involves the IT. This paper demonstrates, however, that EA is primarily aimed at centralized organizational structures and as such has shortcomings when applied to decentralized organizations. Overcoming these deficiencies requires new principles to be introduced and incorporated into EA knowledge. A potential source for these principles are peer-to-peer architectures, which tackles the problem of decentralization in its own way. This paper presents prevalent decentralization principles from peer-to-peer, and how they have the potential to be applied to EA.**

***Keywords*-enterprise architecture, decentralization**

I. Introduction

Organizations with rigid centralized management style fail to sustain dynamic environments due to their inertia in decision making and lack of agility. Political, social and economic systems progressively transforming to distributed, network, and novel organization forms accordingly are emerging [1]. Recently coined terms such as "proactive enterprise" or "liquid enterprise" describe the nature of such organizations. Transparent or dynamically changing boundaries, agile processes, interactions aligned with real-time business goals, and virtual collaborations are all IT-enabled capabilities of emerging organization forms [2].

In [3], organizational structure is defined as "institutional arrangements and mechanisms for mobilizing [...] resources at all levels of the system". The changes to management and operational styles brought on by decentralization requires major changes in organization processes and heavily involves IT.

While emerging technologies serve as the main catalyst for organizational transformations, utilizing the right technologies and evolving thus to digitized business processes to automate organizations core capabilities [4] – is primordial for organizations.

Traditionally, this is addressed by the enterprise architecture (EA) discipline. EA *"defines the underlying principles, standards, and best practices according to which current and future activities of the enterprise should be conducted"* [5]. EA methods and tools produce artifacts to specify the current state of a company's architecture (*architecture as-is*, specify the target architecture (*architecture to-be*), and identify how to best cross the gap between them (*architectural roadmap*).

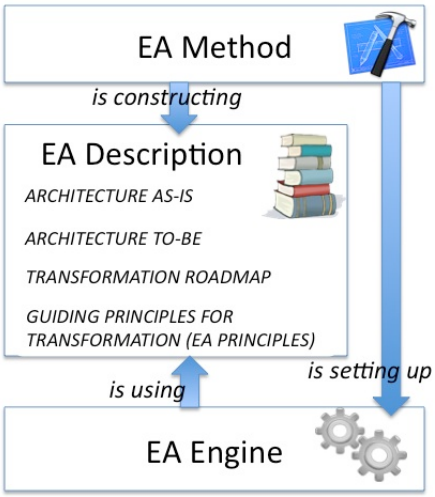

Figure 1. Enterprise Architecture

These produced artifacts are often addressed in literature as **EA description**; the process that an organization has to execute in order to obtain its EA description is called **EA method** (Fig.1). A traditional EA project, though, consists in implementing an EA method and producing an EA description. To assure that the organization will continuously follow the principles and achieve the designated goals after the termination of the EA project a third element has to be defined. We call this element **EA engine**.

Created in early 1990s, the de-facto EA methodologies support organizations in creation and evolution of their IT in *structured and disciplined* way: they focus on *centralization of IT* and its tight binding to the organizational structure and properties (e.g. centralized management). Such properties,

however, do not necessarily exist in decentralized organizations. Consequently, implementation of these methodologies in organizations of 2010s becomes difficult and inefficient, and the role of EA as a driver for IT transformations is compromised.

As an example, consider a public organization acquiring a software system with the objective of integrated facility management across divisions. Divisions were not involved in the decision making process (due to centralized strategic planning) and eventually refused to shut down their local systems and switch to the global one (due to decentralized IT management). As a consequence, the strategic initiative for integration failed; the divisions protected their interests (local systems tailored for their needs), but were still charged for the acquired system they never used (due to centralized budgeting). This example demonstrates a mismatch between the architecture principles (tendency towards integration), architecture engine (the process of prioritizing, evaluating and eventually deciding on the global system to adopt) and the organizational structure that inherits some centralized mechanisms while being strongly decentralized.

We claim that structured and disciplined approach to IT evolution not necessarily has to rely upon IT centralization. Therefore, novel EA concepts are needed to ensure that the development and evolution of IT is *harmonized* with the properties of decentralized organizations.

In this paper, we analyze various forms of organizational structures presented in literature, outline the characteristics of decentralization, and identify the challenges related to decentralization in organizational IT. We define decentralization in organizational IT as a continuum with three phases: Centralized IT, Federal IT and Decentralized IT. The main contribution of this paper is an assessment of the three prevalent EA methodologies (TOGAF, Zachman and FEA) and their capacity to support the decentralization. These three frameworks were chosen as they are highly influential, as evidenced by their extensive coverage in literature, for example [5]–[9]. Furthermore, Sessions [9] identifies them, along with the Gartner Methodology, as making up about 90 percent of the field.

This assessment finally leads us to a set of recommendations for decentralized-aware EA. This paper is part of research work still in its early phases, and as such, empirical validation has not yet been done at this stage.

The remainder of this article is organized as follows: In Section II we discuss the role of EA in organization and provide an overview of three EA methodologies: TOGAF, Zachman and FEA; in Section III we discuss different forms of organizational structure (generic and IT-specific) presented in the literature focusing on their degree of (de)centralization. We outline the main characteristics of decentralization and highlight the challenges related to decentralization in IT. In Section IV we examine how the presented EA methodologies support (de)centralization. In Section V, we propose a set of recommendations for decentralized-aware EA.

II. Enterprise Architecture Frameworks

A. A Common Perspective on Enterprise Architecture

While there is no singular agreed-upon definition for EA, different definitions [4], [5], [8]–[12] do have much in common. EA is a discipline that takes a holistic, design-oriented approach to transforming high-level business vision and goals into the integration of an enterprise's organizational structure, business processes, and information systems. This transformation involves identifying and implementing the necessary change for this to occur. This paper will break the frameworks down into three separate components (Fig.1): EA method, EA description, and EA engine.

The Method aims to lay the groundwork for the EA project. Typically, this involves setting up teams, responsibilities, and the overall process of collecting and approving the EA artifacts (e.g. as-is and to-be architectures) which form the second component, the EA description. The Engine involves setting up a support structure for ensuring the ongoing adoption of the to-be architecture. The remainder of this section will look at three different EA frameworks from the perspective of of these three phases: The Open Group Architecture Framework (TOGAF), the Zachman Framework, and the Federal Enterprise Architecture (FEA).

B. TOGAF

The Open Group Architecture Framework (TOGAF) is an EA framework created by The Open Group.

1) EA Method: TOGAF includes a very detailed EA method, called the Architecture Development Method (ADM), made up of a preliminary phase and eight core phases (labeled A–H) [12, Ch. 5-15]:

Preliminary
: establish initial commitment and governance;

A
: set a high-level vision for the future architecture (includes management approved goals and requirements) to create a "Statement of Architecture Work" for forming contracts and obtaining approval from project sponsors;

B–D
: create the as-is and to-be architectures, and analyze the gap between them;

E–F
: create plans for crossing the gap;

G–H
: concerned with implementation, ongoing governance, and change management.

2) EA Description: TOGAF views architecture from the perspective of four different architecture domains [9]: business (processes and functions), application, data, and technical (specific infrastructure).

The various architectural artifacts in TOGAF are organized across an Architectural Landscape [12, Ch. 20]. Here, TOGAF specifies three levels of detail: strategic, for overall direction setting at the executive level; segment, for

architectures at the level of a specific project or program; and capability, for governance related activities. Additionally, the Architecture Landscape can be partitioned for supporting different organizational units [12, Ch. 40].

TOGAF's Architecture Content Framework describes the outputs of the architecture efforts from the ADM. This includes the "deliverables" that are specified in the contracts and subject to formal approval [12, Ch. 33].

3) EA Engine: TOGAF outlines an ADM phase concerned with the ongoing change management process for the architecture of an enterprise [12, Ch. 16]. In this phase, a governance body sets criteria for determining if a change requires an architecture update if a new cycle of the ADM needs to be started.

TOGAF describes a formal review process for determining compliance with the goal to "first and foremost, catch errors in the project architecture early, and thereby reduce the cost and risk of changes required later in the lifecycle" [12, Ch. 48].

TOGAF outlines a formal approach to architecture governance led by an "Architecture Board" [12, Ch. 47]. The TOGAF Architecture Governance Framework [12, Ch. 50] suggests guidelines for developing a formal architecture governance structure.

C. Zachman

The Zachman Framework was the first EA, first introduced by John Zachman in 1987 [9], [13]. It consists only of a taxonomy, and as such only fits into the EA Description aspect of EA.

1) EA Description: The Zachman Framework breaks down EA into a grid of perspectives. Each perspective is characterized by its target audience and the issue it is aimed at. ZF covers six issues: What (data and entities), How (functional), Where (locations and networks), Who (people relationships), When (events and performance criteria), and Why (motivations and goals) [5]. Each issue is viewed from six different perspectives: executive, business management, architect, engineer, technician, and enterprise users.

The executive perspective provides an estimate of a system's functionality and cost [5]. The business management perspective is a view of how an owner thinks the business operates [14]. The architect perspective takes a systems viewpoint and describes the operations and interactions of the enterprise's systems. The engineer perspective describes the technology and design of individual systems. The technician perspective takes the technically detailed perspective of a "sub-contractor" who is implementing a system. The enterprise users perspective describes the perspective of the system users.

D. FEA

The Federal Enterprise Architecture (FEA)is an effort by the federal government of the United States to create an EA for the entire government. FEA is a complete EA framework, covering all three components of EA. FEA takes an approach where individual organizational units develop their own architectures that fit into an overall framework of common standards and interoperability.

1) EA Description: FEA develops architecture for segments and enterprise services. A segment is a "major line-of-business functionality" [9] for an individual organizational unit (such as an agency or department).

The EA artifacts defined by FEA include baseline segment architectures, target segment architectures and transition strategy (for achieving the target architecture).

2) EA Method: FEA defines a four step iterative process for creating architectures for each segment and service [15]: 1) analysis, where the baseline architecture, current problems, and vision for the target architecture are outlined; 2) definition, where the detailed target architecture of the segment and how to get there is defined; 3) investment strategy; and 4) project planning and implementation.

3) EA Engine: FEA describes "EA governance and management processes" [15, Sec. 2] to control architecture development. These process are implemented to manage standards, enforce compliance, manage collaboration between agencies, and approve architectures for implementation.

FEA defines a value measurement process: "a continuous, customer-focused process relying on feedback from EA stakeholders and other value measures to increase the quality and effectiveness of EA products and services to support business decisions" [15, Sec. 5].

III. Organizational Structure and Decentralization

This section will first discuss the forms of organizational structure defined in the literature. Second, the (de)centralization of current organizations and, as a consequence, their styles of IT governance will be explored. We conclude this section by underpinning the challenges organizations have to face due to decentralization.

A. What is a Decentralized Organization?

Much research has been done on specific forms of organizational structure. Taxonomies of organization forms are defined in [16], [17]. *Classic* and *modern* types of organizational structure are often recognized. Classic types include simple centralized organizations [18], bureaucratic organizations [19], divisional structure and functional structure. Modern types include matrix structures, flat organizations and adhocracies. New forms of organizational structure include collaborative networks, virtual organizations and coopetitions.

According to Robbins [20], organizational structure has three components: complexity, formalization and centralization. Complexity refers to the degree to which activities within the organization are differentiated; Formalization

refers to the degree to which work is standardized; Centralization refers to the degree to which decision making is concentrated at one point in the organization.

Following Luthens [21], (de)centralization can be also defined according to three factors: geographical or territorial concentration of operations, functions, and extent of concentration of decision making powers. In [11], the following characteristics of centralization are defined: the allocation of decision rights, the structure of communication lines, and the choice of forms of coordination.

In a completely centralized organization, all decision making authority would reside with a single, top-level authority. In a completely decentralized enterprise all members would have equal decision making rights. Here, hierarchy manages the interdependencies between the different subunits of the organization and often makes direct interactions and communications unnecessary [22]. Decentralized organizations instead have less formalized communication lines [11], and more fluid, project oriented teams [23].

Centralized organizations lean towards a vertical style of coordination [24] characterized by formal authority, standardization, and planning and control systems. Decentralized organizations lean towards lateral coordination characterized by meetings, task forces, coordinating roles, matrix structures, and networks [24].

Below, we will consider popular forms of organizations, focusing on their degree of centralization.

B. Forms of Organizational Structure and Decentralization

1) Classic Organizational Structures: Pearlson and Saunders offer a thorough description of a pure hierarchical organization structure [11]: Except for the top level position, each position has one superior and zero or more subordinates. Decision rights and communication lines are strictly defined and work their way down from the top. The scope of a position is specialized and strictly defined by your superior and one works in assigned teams. The primary benefit of a hierarchy is that the high levels of management have strict governance and control over the company. Hierarchical organization structures are suited for stable environments.

Hierarchical organizations an be subdivided into simple centralized and bureaucratic organizations: In simple centralized organizations, both strategic planning and operational decision making authority belong to one person at the top. This structure can be found in small and single-owner organizations with only two hierarchical levels. Bureaucratic organizations [19] are characterized by a multi-level hierarchical structure and use of standard methods and procedures for performing work.

Hierarchical organizations generally divide their labor either in terms of common activities or in terms of output. Two organizational structures (Functional structure and Divisional structure) can be identified accordingly.

2) Modern Organizational Structures: Matrix structure is another popular style of organization structure [11] that can be seen as a mixture of functional and divisional structures. In this form, individuals are assigned two or more supervisors covering different dimensions of the enterprise. Pearlson and Saunders state that matrix organization structures are suited for dynamic environments with lots of uncertainty, presumably because their authority structure allows them to cover multiple aspects when making decisions. However, like a hierarchical structure, a matrix structure is a rigid construct with strictly defined roles, communication lines and decision rights. Authority still comes from the top in a centralized manner, even though it becomes more distributed among matrix managers at the lower levels.

A flat organization employs a novel type of structure where only one or two hierarchical levels are defined. Valve Corporation, a software company in the video game industry [25], employs such a structure and is an example of high decentralization. In contrast with the simple centralized organization described above, individual employees have complete freedom: Nobody reports to anyone, and everyone is free to choose their own projects.

Adhocracy [11], [23] aims to discard traditional hierarchies in favor of decentralized decision rights and flexible communication lines connecting the entire enterprise. An adhocracy has a rapidly changing set of project oriented groups that have decision making authority and other powers [20]. Mintzberg describes an adhocracy as “a loose, flexible, self-renewing organic form tied together mostly through lateral means” [18].

3) Post-Modern Organizational Structures: New forms of organizational structure enabled uniquely by modern information and communication technologies Internet emerged recently: collaborative networks [26], virtual (boundaryless) organizations and coopetition [27].

Camarinha-Matos and Afsarmanesh define collaborative networks (CNs) as being composed of “a variety of entities (e.g., organizations and people) that are largely autonomous, geographically distributed, and heterogeneous in terms of their: operating environment, culture, social capital, and goals” [26]. Three common characteristics in various CNs are autonomy in the individual entities, a drive towards meeting common or complementing goals, and the use of an agreed-upon framework for collaboration.

A virtual organization is a group of independent organizations working together to achieve some goal. Coopetitions, as described in [27], are characterized by a complex relationship between firms where they simultaneously compete and collaborate and benefit from both. These entities are engaged into collaboration in response to a specific market situation, customer demand, etc. Such organization structures are grounded on a sustainable collaboration between partners without any centralized control.

4) Decentralization in Organizational IT: According to Rockart et al. [28], changes in business and technology as well as progressive decentralization of organization as a whole drives the changes in roles and structure of IT units. The works presented in [28]–[31] focus on the relation between the structure of an organization and its IT.

Fulk [29] discusses the interplay between communication technology and various organizational forms. The authors consider communication technologies as one of the key enablers of inter- and intra-organizational changes.

In [30], authors study how different organizational forms affect the knowledge transfer in organization. They claim that "Organizational forms enable different kinds of motivation and have different capacities to generate and transfer tacit knowledge."

Weill [31] defines six forms of organizational structures in IT: business monarchy, IT monarchy, feudal, federal, IT duopoly and anarchy. In a *business monarchy* all IT related decisions are made in a centralized manner by the top-level executives. In an *IT monarchy*, a group of IT professionals are responsible for making the decisions in a centralized manner. An *IT duopoly* is characterized by two groups (IT and business executives) collaboratively making decisions. The *feudal* form is much less centralized; individual organizational units are responsible for their own decisions. *Federal IT* aims to balance these through a combination of central IT and IT in the business units. *Anarchy* is a style of governance where small teams or even individuals are responsible for their own decisions.

Many organizations today tend to combine both centralization and decentralization in order to obtain the advantages of both styles: global integration and efficiency due to centralized management in some key areas, and agility and high quality of local customer services due to decentralized decision making in others [28].

Figure 2 maps the organizational forms presented above to an axis depicting the degree of (de)centralization.

For the purpose of our study, we consider three types of organizational structure in IT: *Centralized IT*, where all IT related decisions are made in a centralized manner by the top-level executives, *Decentralized IT*, where each organizational subunit manages its own IT in a completely autonomous and independent manner, and *Federal IT* that can be seen as a combination of central IT management and IT management in the subunits.

C. Challenges of Progressive Decentralization in Organizational IT

The emergence of decentralized organizational structures means significant changes for organizations that adopt them. However, this transformation is not a mere question of "flattening" the organization by shifting authority and decision making power from the top to the bottom. In classic organizations, not only does hierarchy ensure control and coordination, it also manages interdependencies between different subunits of an organization and often makes direct interactions and communications unnecessary [22].

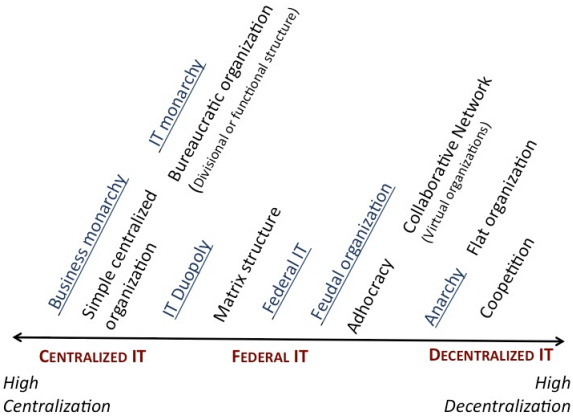

Figure 2. Organizational taxonomy: From Centralized to Decentralized

Therefore, the main challenge related to decentralization and "weakening hierarchy" is a lack of interaction and communication between organizational subunits.

The decentralization of an organization and subsequent change to its management and operation style requires major changes in organization processes and heavily involves IT. Caruso, Rogers and Bazerman [32] highlight the importance of information sharing and coordination for these organizations. According to [28], a major risk of IT decentralization is lack of synergy and integration due to a lack of standardization.

Enterprise Architecture is a discipline that allows an organization to develop and evolve its IT in a manner harmonized with it. It provides methodology and sets up structures for assessing current state of IT (architecture As-Is); for planning, agreeing upon and communicating its future state (architecture To-Be); and for carrying out this transformation. In order for this harmonization to be successful in decentralized organizations, it is important that EA methodologies and structures acknowledge decentralization and help the organization to tackle its related challenges.

In the next section we examine how decentralization in IT is addressed by current EA practices.

IV. Existing EA Practices to Support Decentralization: Analysis and Shortcomings

The field of Enterprise Architecture (EA) emerged in order to combat two increasingly prevalent problems facing enterprises: system complexity and business-IT alignment [9]. As enterprises rely more and more on information systems of increasing complexity, these problems become even more important.

A. TOGAF

1) Concepts supporting a centralized organization:

EA Method and EA Engine: TOGAF's approach to architecture governance involves an Architecture Board "to oversee the implementation of the [architecture] strategy" [12, Ch. 47]. This board has an important role in Architecture Governance, such as "[p]roviding the basis for all decision-making with regard to the architectures" [12, Ch. 47] and enforcing architecture compliance.

Having a single entity responsible for high-level decision making suits well for organizations with strong centralization in IT (Centralized IT to Federal IT in Fig. 2). TOGAF does suggest that the board has enterprise-wide representation [12, Ch. 47] which may support some level of decentralization, however it suggests the representation comes in the form of "senior managers"; a concept primarily from traditional organization structures.

Throughout TOGAF, references are made to the existence of a bureaucratic or hierarchical centralized structure in place; some examples:

- A *formal governance framework* for all architectural material is specified in the preliminary phase, a concept related to the rigid forms of traditional organizational structure.
- After the completion of "Phase A: Architecture Vision", TOGAF requires approval of the current vision of the architecture. This requirement assumes there is someone with a higher level of decision-making authority to give approval.
- The set of strategic architectures from the Architecture Landscape which is meant for the "executive level" [12, Ch. 20].

EA Description: TOGAF suggests the development of architecture principles that "define the underlying general rules and guidelines for the use and deployment of all IT resources and assets across the enterprise" [12, Ch. 23]. Having a central set of principles that is to be applied to an entire organization supports centralization.

TOGAF includes the concept of an Architecture Repository for storing all architectural artifacts and deliverables. Having a single place to store all information is highly supportive of centralization.

2) Concepts supporting decentralized organization:

EA Method and EA Engine: TOGAF supports decentralization through the concept of *partitions*. The Architecture Landscape can be divided into separate parts in order to support "federated architectures – independently developed, maintained, and managed architectures that are subsequently integrated within an integration framework" [12, Ch. 40].

This supports the idea of different organizational units developing their own individual architectures. The mechanism for integrating the individual architectures under the roof of the corporate architecture is not explicit.

TOGAF indirectly supports decentralization through the suggestion that it be *tailored to fit the needs of the enterprise*. This allows TOGAF to support any kind of enterprise, but the guidelines provided are minimal.

B. Zachman

1) Concepts supporting centralized organization:

EA Description: The Zachman Framework aims to model a complete enterprise using a matrix of 36 elements, with alignment and composite integration relations defined between these elements.

The perspectives of Zachman Framework line up with a bureaucratic organizational structure: the defined views (from executive to user) constitute an explicit organizational hierarchy. Clear separation between domains make this framework suitable for matrix organizations as well.

The lack of flexibility in definition of domains and views and the requirement to fill in the matrix is perhaps the Zachman Framework's main shortcoming with respect to decentralization. A primary aspect of decentralized organizations is their high level of flexibility. For a decentralized organization where both roles and domains are not uniformly defined (implicit) for sub-units, the use of the Zachman Framework becomes difficult, if at all possible.

EA Method and EA Engine: Providing a schema for organizing architectural artifacts of an enterprise, the Zachman Framework does not imply any particular method for collecting these artifacts (what we call EA Method in Fig. 1). Neither does it suggest anything the set of structures that we call EA Engine.

Therefore, tailoring and implementation of Zachman framework for a concrete organizational structure depends on experience of the EA (consultancy) team.

To summarize, the Zachman Framework provides a detailed taxonomy of EA artifacts that supports a hierarchical view on the organization. The application of this framework in decentralized organizations remains unclear.

C. FEA

1) Concepts supporting centralized organization:

EA Description: Through the use of a common set of *reference models*, FEA prescribes standards that are to be followed throughout the organization. This limits the flexibility that the individual organizational units have and makes this framework suitable for bureaucratic organizations with a high level of standardization of its processes.

In FEA, however, individual organizational units have the freedom to develop their own architecture as long as it fits in to the set standards. This supports some level of decentralization and suits to organizations with federal structure, where individual units have input into decisions.

EA Method and EA Engine: Segment architecture development is defined by FEA as a collaborative approach conducted by a team composed of business experts, enterprise architects and technical experts. FEA defines a set of segment architecture stakeholders and their roles (

[15, Table 2-2]) in segment architecture development. For example, the role of senior management is defined to set the agency strategic goals. These roles naturally line up with the centralized to federal organization of IT (Fig.2).

The mechanism for integrating the segment architectures under the roof of the corporate architecture is assured by specific governance and management processes which, though implying different stakeholders, remain centralized.

All steps of segment architecture development are supervised by a manager, pointing on centralized management and budgeting.

Transition strategy is defined for the agency level though it is assessed on the global level. Governance-wide collaboration and reuse based on standards is outlined by FEA as an important part of EA transition strategy.

2) Concepts supporting decentralized organization:

EA Description: The resulting segment architecture is positioned by FEA as a shared vision for business and IT transformation within a core mission area or common service. Each segment can have its own architecture that responds to its business needs.

EA Method and EA Engine: The development of *segment architectures* is described as a collaborative process between EA architects and other stakeholders. The focus is placed on the "reconciliation" of the segment architecture with an agency architecture and cross-agency initiative, emphasizing the importance of cross-agency collaboration, common opportunities and initiatives.

Architectural analysis and architectural definition steps of segment architecture development involve business owners at the agency level who define business and information management requirements for the segment. This ensures local interests are looked after within a corporation.

FEA is targeting groups of independent federal agencies with the objective to increase their interoperability and quality of service. Among three EA methodologies considered in our study, FEA is the only one recognizing the need of inter- and intra-agency cooperation and communication. Nevertheless, many of the concepts on which the EA method and EA engine of FEA are grounded remain strongly centralized.

V. Towards Definition of Decentralized EA

The challenge of decentralization is not a new one; other efforts have been able to address their view on it with success. The specifics of the challenge varies between domains, however there may exist general principles that can be taken and applied to EA.

One such effort is peer-to-peer architectures, which "typically lack dedicated, centralized infrastructure, but rather depend on the voluntary participation of peers to contribute resources out of which the infrastructure is constructed" [33].

We argue that peer-to-peer is a relevant concept to decentralization in EA for two reasons. First, individuals in highly decentralized organization are able to contribute to the enterprise in a manner that is completely up to them. This is similar to peers in a peer-to-peer system, where the peers participate in a completely voluntary manner. Second, the challenge that peer-to-peer systems overcome is similar to the main challenge faced by decentralized organizations: "to figure out a mechanism and architecture for organizing the peers in such a way so that they can cooperate to provide a useful service to the community of users" [33]. This is similar to the main challenge facing decentralized organizations – a lack of cooperation – previously identified.

With EA being a potential solution to this challenge of decentralization in organizations and the parallels between the domains of peer-to-peer systems and decentralized organizations, we propose that peer-to-peer principles may be applicable to EA for enhancing their support of decentralization. This section will briefly present and discuss two relevant principles from peer-to-peer.

A. Peer production

Benkler defines peer production as "production systems that depend on individual action that is self-selected and decentralized, rather than hierarchically assigned" [34]. Peer production works on the idea of the individuals willingly coordinating with one another by expressing their own views while understanding the views of others.

Peer production takes many different forms. One example are user-driven media sites such as Reddit and Slashdot, which follow a peer-production model for producing "relevance/accreditation" [34] on user-submitted content. On these sites, the users have the ability to vote on the submitted content in order to decide on the content's relevance or credibility. Another example of relevance production are crowdfunding sites such as Kickstarter where individuals decide on the funding of user-submitted projects by giving their own money. Peer production is also used to produce content, such as in the case of Wikipedia, a completely user-driven encyclopedia.

If we view enterprises as being composed of *peers*, the idea of peer production becomes useful for EA. For example, the EA Engine of TOGAF relies on an Architecture Board responsible high-level decisions and governance. Instead of a central board responsible for making decisions, a model based on the principle of peer production for relevance/accreditation could be used instead. This would better support decentralization as decision making would then be distributed amongst the peers that make the organization.

B. Trust management in peer-to-peer

Due to the fact that peers in peer-to-peer systems are able to operate in a completely independent manner, there exists the problem of knowing whether or not the contribution made by a peer is trustworthy or not. Consequently, some researchers have proposed various methods for determining trust in a peer-to-peer environment. For example, Aberer and

Table I
EXISTING AND PROSPECTIVE SUPPORT OF PROGRESSIVE DECENTRALIZATION BY EA FRAMEWORKS

EA component	Existing support for centralized organizations	Existing support for decentralized organizations	Applicable P2P principles for a solution
EA method:	Approval process based on hierarchy; architecture development is coordinated, supervised and evaluated by well-defined roles in a company; EA teams coordinate architectural work and communicate results; results are controlled and evaluated centrally by program manager)	Federated architectures; possibility to adapt ADM for a specific organization; architecture development process involves multiple stakeholders	peer production principles for creation and evaluation of EA artifacts; P2P trust management replacing approval mechanism
EA description:	Strategic level architectures; hierarchy of architecture principles; a common set of reference models; hierarchical organization of EA artifacts with explicitly defined roles and domains (Zachman)	Architecture partitions; architecture reference models; segment architecture; the concept of "shared vision"	User-driven content submission and change management of the content (i.e. the structure is defined by the users)
EA engine:	Architecture board; formal governance framework; common principles for an entire organization (i.e global commitment is taken for granted); centrally managed architecture repository	integration of various (segment) architectures is assured by (centralized) management and governance	Peer production for relevance/accreditation (e.g. decision making in budgeting, strategy, opportunity evaluation, solution evaluation); user-driven content submission and change management of the content; P2P trust management

Despotovic [35] have proposed determining whether a peer is trustworthy or not based on a peers history of interactions with other peers in the system. This assessment is performed by the individual peers, and as such, is appropriate for a peer-to-peer environment. TOGAF employs the idea of an approval process grounded on the presence of centralized authority to ensure that the presented architectural material is valid for the enterprise. In a decentralized environment, this central authority is not likely to exist. Peer-to-peer trust management may offer a solution here: Instead of explicit approval, the acceptance of a peer's contribution to EA can be based on a peer's level of trustworthiness.

VI. CONCLUSION

In this study we have analyzed the problem of non-fit between emerging decentralized organizational environments and established EA methodologies.

We have argued that decentralization in organizational structures and IT governance is common in many modern organizations. These organizations are following different patterns by fostering entirely new relationships between business processes and IT. The classification of organizational forms of IT presented in Section III, was used to assess if the dominant EA methodologies can support them.

Current EA frameworks fail to solve this major concern in decentralized environments. We have surveyed Zachman Framework, TOGAF and FEA, and concluded that the first is unable to support any significant aspect of decentralization. While the latter two provide some basic flexibility, in TOGAF, it is mainly facilitated by the ability to have a different architecture for organizational units and by providing space for new methods for the architecture development; in FEA, the conclusions are similar, while the top-level organization standards need to be obeyed by all units. Consequently, implementations of these methodologies are heavily limited to support new decentralized organization patterns fostered by virtual organizations, collaborative networks, coopetitions, and others. Lastly, we discussed how the application of specific peer-to-peer architecture principles–in particular peer production and trust management–could be projected onto the problem of employing EA in organizations following a decentralized organizational pattern.

The aim of this research is to contribute to a 'state of the art' on enterprise modeling methodologies by analyzing the decentralization of organizations and supporting business patterns and technologies, and thereby the consequences of this trend to the requirements for new approaches to the use and management of IT resources. Regarding future work, our next steps involves contrasting the presented theories and argumentations empirically, i.e. by mapping them to EA of different organizations. Such an ongoing study concerns an organization in the public sector of Sweden, exposing many of decentralized behavior as discussed in this paper.

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