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A Comparative Analysis of the Integration of Mobile IT/Cloud Elements in Enterprise Architecture Frameworks: Towards the Era of Digital IT

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Abstract: Since the year 2000, Enterprise Architecture has been the object of focus as a method for promoting an IT architecture that establishes consistency between corporate business and IT strategies, and it has been applied mostly in global corporations. However, with the recent progress in Mobile IT technology and Cloud computing towards the era of Digital IT, in the IT systems of global corporations, the shift from conventional on premise server-based IT systems to Cloud computing, such as Software as a Service (SaaS), Hybrid Cloud, and connected Mobile IT systems as core elements of Digital IT, has become more pronounced. In promoting Enterprise Architecture, EA based upon an approach compatible to the cutting-edge IT technologies of Mobile IT/Cloud computing will be required by global corporations. This paper elucidates key points for EA methods to respond to the cutting-edge IT technology that will be required in the future by conducting a comparative analysis of the support environments of Mobile IT elements and related Cloud computing technology in each EA framework currently used widely in many global corporations.

Key words: enterprise architecture; EA; enterprise mobile IT; cloud computing; integration; digital IT
JEL code: I, O33

1. Introduction

With many global corporations promoting IT projects since the turn of the century, such companies have encountered a variety of changes, such as the progress of new technologies, globalization, shifts in customer needs, and new business models. Significant changes in cutting-edge IT technology due to recent developments in Cloud computing and Mobile IT (such as progress in big data technology), in particular, have arisen as new trends in information technology. In addition, because of improvements in business competitiveness in these corporate markets and productivity, there is a tendency towards depending on IT, in particular, sensitivity towards the above-mentioned trends. Furthermore, major advances in the abovementioned technologies and processes have created a "Digital IT economy", bringing about both business opportunities and business risks, forcing enterprises to innovate or face the consequences. Many enterprises are not well prepared for the rapid pace of digital IT

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disruption, which requires continual change as a reality of the Digital IT economy (Boardman & KPN, 2015). The architecture model is applied with the purpose of allowing easy to understand control of the complexity of this reality (Land et al., 2009). The ISO/IEC/IEEE 42010:2011 standard also recommends providing architectural descriptions of systems to manage their escalating complexity and alleviate the risks incurred during the development and evolution of these systems (Alwadain et al., 2013). From a comprehensive perspective, Enterprise Architecture encompasses all enterprise artifacts, such as business, the organization, applications, information, data, and infrastructure, to establish current architecture visibility and future architecture to lead to a roadmap (Buckl et al., 2010). To continue to deliver these benefits, EA frameworks need to embrace change in ways that adequately consider the emerging new paradigms and requirements that affect EA, such as enterprise Mobile IT/Cloud computing (Alwadain et al., 2014).

Mobile IT has received the most focus among recent cutting-edge IT fields, and contributes greatly to business by realizing flexible working styles that involve Bring Your Own Devices (BYOD). Mobile IT consists of a mobile management platform to manage mobile applications and data, and mobile devices. Mobile IT applications, on the other hand, consist of Web services (including APIs and connection to the Cloud (Software as a Service — SaaS)) sometimes developed with an agile approach of Services that involve Service-Oriented Architecture (SOA). Thus, enterprise architects have to adapt their methodologies and concepts to manage the complex service architecture (Postina et al., 2010). Services are increasingly being perceived as one of enterprises' essential assets that need to be considered and integrated in EA (Correia & Silva, 2007; Khoshnevis et al., 2009). Correia and Silva (2007) emphasized the need to capture services within the EA frameworks. They highlighted the importance of an integrated and cohesive vision of services in EA to increase organizational agility.

Cloud computing is also one of the most discussed fields in advanced IT in recent years and is extremely closely related to Mobile IT. Cloud computing can contribute to cost reductions and profit increase with minimizing IT assets and promoting application standardization. Many Mobile IT applications operate with Cloud-based software that can be used as SaaS. Other existing Cloud computing formats include Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). Each of these formats has architectures that directly affect organizational EA (Khan & Gangavarapu, 2009). IT applications that run on these Cloud computing formats are composed of the above Web services with the design approach of SOA. However, "current EA methods do not take into account handling the complexity of dynamic strategic changes in corporations nor dynamic changes in IT trends" (Alwadain et al., 2014), and EA cannot cope with the great changes in leading IT trends due to recent developments in Cloud computing. It has been indicated that "current IT trends such as Cloud computing are a challenge for EA" (McKendrick, 2010).

The EA framework selected offers partial support for Mobile IT, Cloud computing, and Services (e.g., The Open Group Architecture Framework — TOGAF, Department of Defense Architecture Framework — DoDAF). Moreover, this paper addresses the aforementioned challenge by comparing the widely used EA frameworks based on the identification of the Mobile IT/Cloud-related elements in these frameworks and their positions in each framework. In doing so, this paper addresses the following research question: How do major Enterprise Architecture frameworks integrate these Mobile IT/Cloud-related elements as an example of EA evolution? The contribution of this paper is that it presents the first thorough analysis and comparison of the EA frameworks in terms of their integration of Mobile IT/Cloud-related elements in order to better understand and integrate the Mobile IT/Cloud in EA frameworks. Another contribution is to lead businesses to use appropriate architecture models/guidance for enterprise Mobile IT, reduce cost, and increase profit using proper architecture models/guidance for Cloud computing in the EA frameworks. Therefore, the Mobile IT/Cloud-related elements are identified and each framework assessed in terms of capability to capture these elements after comparing the frameworks.

The remainder of the paper is structured as follows. Section 2 briefly reviews the literature on EA and Mobile IT/Cloud computing, and briefly explains Cloud computing architecture while clarifying the concepts of SOA and Microservices that involve Mobile IT application trends. Section 3 presents the research design of this study, and Section 4 describes and analyzes five widely used EA frameworks that support Mobile IT/Cloud computing and Services as part of SOA. Section 5 compares their Mobile IT/Cloud integration with Services. Section 6 discusses the findings, and Section 7 concludes and provides an outlook on future research.

2. Related Research

2.1 Literature Review

In the past ten years, EA has become an important method for modeling the relationship between the overall image of corporate and individual systems. In ISO/IEC/IEEE42010:2011, architecture framework is defined as "conventions, principles, and practices for the description of architecture established within a specific domain of application and/or community of stakeholders." Furthermore, in the TOGAF (2011) technical literature, it is defined as "a conceptual structure used to develop, implement, and sustain an architecture". In addition, EA visualizes the current corporate IT environment and business landscape to promote a desirable future IT model (Buckl et al., 2010). EA is required as an essential element of corporate IT planning; it is not a simple support activity (Alwadain, 2013), and it offers many benefits to companies, such as coordination between business and IT, improvement in organizational communication, information provision, and reduction in the complexity of IT (Tamm et al., 2011). In order to continue to deliver these benefits, EA frameworks need to embrace change in ways that adequately consider the emerging new paradigms and requirements that affect EA, such as the paradigm of Cloud computing or enterprise mobility (Alwadain et al., 2014).

Mobile IT computing is an emerging concept in general that uses Cloud services provided over mobile devices (Muhammad & Khan, 2015). In addition, Mobile IT applications are composed of Web services. There is not much literature that discusses EA integration with Mobile IT and the relationship between the two; however, integration with SOA has been discussed greatly. Many organizations have invested in SOA as a crucial approach for achieving agility as an organization that can manage rapid change (Chen et al., 2010). In the meantime, there has been a recent focus on Microservices architecture, which allows rapid adoption of new technologies, such as Mobile IT applications and Cloud computing (Newman, 2015). This paper considers both perspectives.

In terms of Cloud Computing, mobile devices also widely use Cloud computing capabilities, and many Mobile IT applications also operate with SaaS Cloud-based software (Muhammad & Khan, 2015). There is literature that concerns the integration and relationship between EA and Cloud computing, but it is scarce. Although Cloud computing formats consist of three general services — SaaS, PaaS, and IaaS — under the current EA framework, there is merely a modeling of only this computing format and the business components managed by this company. Considering recent dynamic moves in business and the characteristics of Cloud computing, it is necessary for companies to link the service characteristics (those similar to the above Mobile IT characteristics) of EA and Cloud computing (Khan & Gangavarapu, 2009). It is said that the traditional EA approach requires months to develop an EA that allows Cloud technology in order to realize a Cloud adoption strategy, and organizations will demand adaptive enterprise architecture to iteratively develop and manage an EA adaptive to the Cloud technology (Gill et al., 2014).

In addition, the Open Platform 3.0 Standard was developed and approved by The Open Group, and it focuses on emerging technological trends, such as Cloud computing and Mobile IT, that create new business models. In this environment, many basic architecture models are noted, including Mobile IT/Cloud computing. Furthermore, the core elements of mobile devices, applications, device management, and application management, as well as those of Cloud computing, which are SaaS, PaaS, and IaaS, have been proposed (Boardman & KPN, 2015). On the other hand, the pubic standards group OASIS (MacKenzie et al., 2006) has introduced the SOA Reference Model, which presents SOA core elements of service and service interface.

2.2 Cloud Computing Architecture

NIST Cloud computing definition highlights three Cloud service models: SaaS, PaaS, and IaaS (Gill, 2015). Figure 1 shows the "high-level architectural components of Cloud computing from an enterprise point of view." The architectural components shown in Figure 1 are divided into two types: "Service-based" enclosed in an oval and "Resource-based" enclosed in a rectangle. Although the "Service-based" component is used by "Cloud computing consumers", the "Resource-based" component supports the "Service-based" (Khan & Gangavarapu, 2009) component.

PaaS is a platform hosted at IaaS. PaaS includes both system software and Integrated Development Environment (IDE), in addition to a programming language, test tools, Web, application, database and file servers, and integrated utilities and infrastructure software (Gill, 2015). As shown in Figure 1, the PaaS key architectural component is the "Development Resource" including development platforms. In addition, "Service-based" components include "Composition" (software components, utilities to build applications) and "Execution" (application on the platform to run) (Khan & Gangavarapu, 2009).

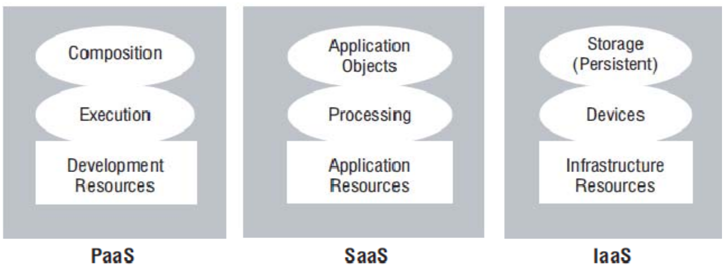

Figure 1 High-level Architectural Components of Cloud Computing from EA Perspective

Source: Cutter IT Journal, November 2009.

SaaS is a software application developed and deployed, or run, by the underlying PaaS. The SaaS interface can be accessed through client and API interfaces (Gill, 2015). As shown in Figure 1, the main SaaS "Resource-based" component is "Application Resources", which includes virtualization and middleware. Although "Service-based" components have "Application Objects" (modules, process logic, and databases), the "Processing" components change "customer's data" into "output" (Khan & Gangavarapu, 2009).

IaaS provides a pool of computing, network, storage, memory, and other related infrastructure resources located in a particular facility. IaaS accommodates PaaS and SaaS (Gill, 2015). As shown in Figure 1, the IaaS key architectural component is "Infrastructure Resources," which includes servers, disks, devices, and CPUs. With regard to the other two "Service-based" components, IaaS includes "storage of consumer's data" (permanent data storage) and "devices" (using the physical computing resources of networks, servers, and CPU power). In network components, there are also low-level architectural components of bandwidth, routers, and switches (Khan & Gangavarapu, 2009).

2.3 SOA and Microservices

SOA and *Microservices* vary greatly from the perspective of service characteristics (Richards, 2015). In this section, we explain these characteristics.

SOA is a collaborative design approach for multiple services to offer various capabilities; its design approach has been used for large monolithic applications (Newman, 2015). In terms of service types and roles in SOA, there are extremely clear and formal service classifications. The SOA architectural pattern, shown in Figure 2, defines four basic types (Richards, 2015).

Business services are abstract, high-level services that define the core business operations performed at the enterprise level, with, e.g., XML, Web Services Definition Language (WSDL).

Enterprise services are concrete, enterprise-level services that implement the functionality defined by business services. As shown in Figure 2, middleware components bridge abstract business services and corresponding actual enterprise services. Enterprise services are generally shared across an organization (Richards, 2015).

Application services are application-specific services bound to the specific application context. Application services provide specific business functions not seen at the enterprise level, and they can be directly called through dedicated user interfaces or enterprise services.

Finally, infrastructure services are those services that implement nonfunctional tasks, such as auditing, security, and logging, almost similar to the Microservices architecture. In SOA, it is possible to call infrastructure services from application or enterprise services (Richards, 2015).

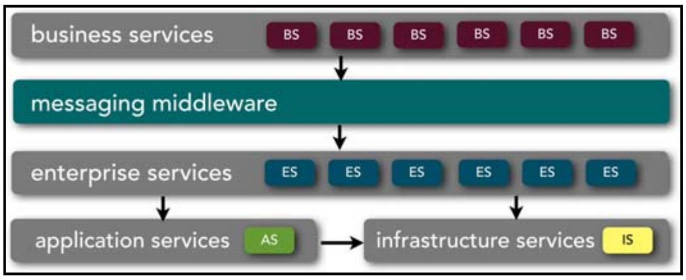

Figure 2 SOA Taxonomy

Source: Microservices vs. Service-oriented architecture, O'Reilly, November 2015

Microservices are the approach to distributed systems that promote the use of finely grained services with their own lifecycles. Such services collaborate together while integrating new emerging technologies to solve the potential problems of many SOA implementations (Newman, 2015). Microservices architecture is identified as the optimal architecture for Cloud-hosted solutions. Composed of multiple cooperating Microservices, Microservices architecture is enabled by Mobile IT applications, the Web, and by mounting wearable devices that will become popular in the future (Familiar, 2015).

Microservices categories differ decisively from SOA service categories. Microservices architectures have limited service taxonomy in terms of service type classification. As shown in Figure 3, Microservices are mainly composed of only two service types.

While functional services support specific business operations and functions, infrastructure services support nonfunctional tasks, such as authentication, permissions, auditing, logging, and monitoring, because infrastructure services are not external facing, but are recognized as “private shared services” that can be used internally only for other services. Functional services can be accessed externally and are generally not shared with other services (Richards, 2015). Microservices allow early adoption of new technology, such as Mobile IT applications and Cloud computing (Newman, 2015). Composed of multiple cooperating Microservices, it can be implemented as a Mobile IT application (Familiar, 2015).

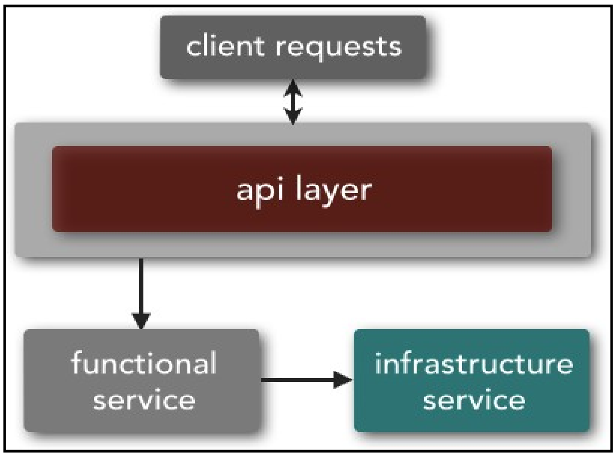

Figure 3 Microservices Service Taxonomy

3. Research Design

This research proceeds with the following three steps. First, we identify the EA framework, which is the scope of this research. From the perspective of integrating the elements of Mobile IT/Cloud computing, the second step is to review each EA framework in order to identify these elements of Mobile IT/Cloud. The final step is a cross-sectional comparison of the elements of the selected EA frameworks in order to identify effective parts for making architecture models/guidelines/processes in Mobile IT/Cloud computing. The goal of such models/guidelines/processes is to promote EA that can lead to business contributions by realizing flexible working styles that involve BYOD in Mobile IT. Other goals are to lead to cost reductions and profit increase with minimizing IT assets, and promote application standardization in Cloud computing in corporations. This is explained in the results described in Section 5 and summarized in Table 1.

To start, the first step is to select an EA framework for this research. The criteria for this selection are: (A) widely used and highly evaluated EA frameworks and (B) an EA framework that supports Mobile IT/Cloud computing and Web service elements. According to a survey in the Journal of Enterprise Architecture (2013), from the perspective of the “widely used” criterion, TOGAF, Zachman, Gartner, Federal Enterprise Architecture Framework (FEAF), and DoDAF are the most widely used EA frameworks, and it was decided that TOGAF, FEAF, and DoDAF are “highly evaluated.” Furthermore, according to Microsoft (2007), Zachman, TOGAF, FEAF, and Gartner are the most commonly used EA frameworks.

In this paper, the second criterion for EA framework selection is integration with the elemental framework of Mobile IT/Cloud computing and Services (part of SOA). From the perspective of integrating the elements of Mobile IT and strongly directly linked Cloud computing, Gill et al. (2014) argued that FEAF, TOGAF, Zachman, and the Adaptive Enterprise Architecture framework (Gill, 2013) are suitable. In addition, TOGAF, FEAF, DoDAF, and the British Ministry of Defence Architecture Framework (MODAF) are discussed from the perspective of integration with SOA elements, which have Web services (Alwadain, 2013; Federal CIO Council, 2008; US Department of Defense, 2009).

In addition, because the Gartner framework is limited to commercial use, complete access is not possible and it is therefore outside of our scope (Franke et al., 2009). Moreover, because the Zachman framework does not provide an enterprise architecture process for implementing and operating an enterprise architecture capability (Gill, 2015), this is also out of our scope at this time.

In the second step, we identify the Mobile IT/Cloud computing elements in the selected EA framework and have listed them in Table 1. The gray colored zones in Table 1 indicate the results of previous research by Alwadain in 2013, but we updated these results, such as Application Service in MODAF, after finding the differences from those in the previous research while performing another evaluation. The yellow colored zones indicate the results of the new investigation regardless of the existence of equivalent previous research by Alwadain in 2013 because FEAF (Federal Enterprise Architecture Framework 2013) changed its own model definition, with the exception of BRM, and we found some elements of Mobile IT/Cloud computing/Service in additional perspectives, such as Capability View in DoDAF and Strategic/System Viewpoint in MODAF. The white colored zone represents the results of the new investigation at this time. Because the status of these elements is different in each category, such as Mobile IT, Cloud computing, and Services, which have affinity among each other, we formulated Table 1 by category in order to evaluate the elements in each category. In terms of the Mobile IT Category as Technology Architecture, we extracted the appropriate elements from Mobile Computing-related models in the Open Platform 3.0, and added the API elements from those related to Microservices as depicted in Section 2.3. From the perspective of the Mobile IT-related Cloud category as Technology Architecture, we placed “SaaS”, “PaaS”, and “IaaS” in Table 1 as the three Cloud service models of the NIST Cloud computing definition described in Section 2.2, and we added “Cloud Interface” in Table 1 because this element is essential to Cloud computing, such as the Hybrid Cloud model and Mobile IT applications. We also added “Other” for new emerging ones. Considering the recent trend in Mobile IT/Cloud system development of shifting to the Microservices approach from conventional SOA, there is no definition of Service elements in Microservices from SOA-related elements, and thus, elements that specialize in SOA only, such as those in the Service Contract category and Service policy, and Service channel, are excluded from Table 1. Moreover, in the service category as Application Architecture, we enclosed in parentheses the Microservices elements that are equivalent to those of SOA, which fall under SOA Web services.

When Mobile IT/Cloud computing-related elements are clearly expressed in the framework meta-model, models, View Points, and architecture processes, this is taken as extremely hard evidence that these elements are clearly integrated, and the symbol “**” is used in Table 1 to indicate this. Similarly, when these elements are clearly expressed in the framework text, this is also taken as hard evidence, and the symbol “*” is used in Table 1. In reference to this table, many corporations can look for the current reference information for the architecture models/guidelines/processes in Mobile IT/Cloud computing, and they can define appropriate architecture models and guidelines for enterprise Mobile IT/Cloud computing by referring to the parts marked as “**” in each EA framework, which can be beneficial for EA promotion in corporations and can lead to business contributions, cost reduction, and profit increase.

Table 1 Mobile IT/Cloud Elements in EA Frameworks

EA Frameworks		TOGAF 9			FEAF					DoDAF v2.0		MODAF		Adaptive EA	
Layers (views) Mobile IT/Cloud elements		Business	Information Systems	Technology	BRM	DRM	ARM	IRM	SRM	Capability View	Services View	Strategic /System Viewpoint	Service Oriented Viewpoint	Enterprise Service System	Cloud EA Capability
Mobile IT Category (TA)	Mobile Device			*	*		*	**	**	*		*			*
	API		*	*		*	**								*
	Mobile Device Manager														
	Mobile Application Controller														
Mobile IT-related Cloud Category (TA)	SaaS							*		*	*				**
	PaaS							*		*					**
	IaaS							*		*					**
	Cloud Interface														*
	Other						*	**	*	*					**
Services Category (AA)	Service									*	**		**	**	**
	Business Service (micro service)	**			**	*	*				*			**	**
	Application Service (functional service)		**				*			*	*		*	**	**
	IS Service (functional service)		**											**	**
	Enterprise Service (functional service)				*									*	
	Infrastructure Service (infrastructure service)			*				*						**	**
	Platform Service (functional service)			**										**	**
	(Service based) Mobile Application														*
Actors Category	Actor	*			*				*					**	**
	Service Consumer	*		*	*								**	*	
	Service Provider	*	*	*	*								*		
	Performer									*	**				
Interfaces Category	Business Interface														**
	Application Interface						**								*
	Infrastructure Interface														*
	Service Port										**				
	Service Interface	*	*	*	*		*						**	*	

4. Mobile IT/Cloud Integration in EA Frameworks

This section offers an investigation and comparison overview of how Mobile IT/Cloud computing elements are integrated into the selected EA frameworks in terms of the status of their integration and their relative position in each view and layer.

4.1 TOGAF (The Open Group Architecture Framework)

TOGAF is a framework for developing enterprise architecture with a detailed method and supporting tools, developed and maintained by members of The Open Group. Architecture Development Method (ADM) is the core of TOGAF. It describes a step-by-step approach to developing Enterprise Architecture (ISO/IEC JTC 1/SC7 Architecture Guidance, Garnier et al., 2014). TOGAF is not attached to government enterprises. It is a generic and comprehensive framework that can be tailored for the development of effective enterprise architecture capability for technology-enabled enterprise adaptation (Gill, 2015). With regard to the remaining parts of TOGAF, “the content framework” provides a conceptual meta-model for describing architectural artifacts. “The enterprise continuum” is a virtual repository for storing architectural models and architectural descriptions. “The TOGAF reference models” are divided into the TOGAF Technical Reference Model and the Integrated Information Infrastructure Reference Model (Buckl et al., 2009; The Open Group, 2009c).

Web Service/SOA elements in TOGAF are found in its meta-model and discussed further in its documentation (The Open Group, 2009b, 2009c). TOGAF has three layers. First, in the business architecture, a business service is identified in the meta-model. In the application architecture, application and information system services are represented in the meta-model. In the technology architecture, a platform service is identified in the meta-model (Alwadain, 2013). There is a specific notation of the Mobile IT Category, particularly in the Mobile Device part of “Enterprise Security View” and “Communication Engineering View” under the content framework Technology Architecture portion. In addition, there is mention of the APIs under Application Architecture and Technology Architecture in ADM and TRM. In TOGAF, a service interface is identified as part of all three architectures of business, application, and technology, whereas there is no element of a Cloud Category.

4.2 FEAF (Federal Enterprise Architecture Framework)

FEAF (Federal Enterprise Architecture Framework, 2013) is a comprehensive framework for developing and maintaining the enterprise architecture capability of the Federal Government. FEAF provides a common and standardized approach and principles for developing and sharing architecture information between agencies (Gill, 2015). FEAF was developed by the US Federal Chief Information Officers Council (Federal CIO Council, 2008). The core of FEAF is a Collaborative Planning Methodology (CPM) and Consolidated Reference Model (CRM). CRM specifies six interrelated reference models: Performance Reference Model (PRM), Business Reference Model (BRM), Data Reference Model (DRM), Application Reference Model (ARM), Infrastructure Reference Model (IRM), and Security Reference Model (SRM) (Gill, 2015). The reference models are intended to standardize terms and definitions in EA contexts and improve sharing and collaboration across the entire federal government (Federal CIO Council, 2008).

First, with regard to FEAF Mobile IT Category elements, Mobile Devices appear in SRM and IRM meta-models and in ARM and BRM. APIs are produced in the ARM meta-model and DRM (Federal Enterprise Architecture Framework, 2013). With regard to FEAF Cloud Category elements, Cloud Computing is produced in IRM meta-models, and SaaS, PaaS, and IaaS are noted in IRM Cloud First Initiatives. Furthermore, Cloud

Computing is noted in ARM and SRM (Federal Enterprise Architecture Framework, 2013). Concerning FEAF Web Service/SOA elements, Business Service appears in the BRM meta-model, DRM, and ARM. Application Service is noted in ARM, Enterprise Service in BRM, and Infrastructure Service in IRM (Federal Enterprise Architecture Framework, 2013). Service Consumer and Service Provider are also identified in BRM (Federal Enterprise Architecture Framework, 2013; Federal CIO Council, 2008). Moreover, Application Interface appears in ARM meta-models (Federal Enterprise Architecture Framework, 2013), and Service Interface is noted in ARM (Federal CIO Council, 2008).

4.3 DoDAF (Department of Defense Architecture Framework)

DoDAF is an architecture framework for the United States Department of Defense and defines a standard approach for describing, presenting, and integrating DoD architecture. DoDAF provides the guidance and rules for developing architecture descriptions to show a common denominator for understanding, comparing, and integrating Systems of Systems (SoS), and interoperating and interacting architectures (ISO/IEC JTC 1/SC7 Architecture Guidance, Garnier et al., 2014). DoDAF provides a six-step architecture development process: Define Architecture Use, Define Architecture Scope, Define Required Architecture Data, Manage Architectural Data, Analyze Architecture Data, and Document Architecture (according to the intended architecture use or needs). The DoDAF meta-model is structured around the interoperability of processes and systems (Gill, 2015). DoDAF v2.0 has different layers (viewpoints): Systems Viewpoint (SV), Service Viewpoint (SvcV), Data & Information Viewpoint (DIV), Operational Viewpoint (OV), Standards Viewpoint (StdV), Capability Viewpoint (CV), Project Viewpoint (PV), and All Viewpoints (AV) (US Department of Defense, 2009). DoDAF provides features such as a concrete EA process, meta-model, models, viewpoints (Gill, 2015).

First, with regard to Mobile IT Category elements in DoDAF, Mobile Devices are mentioned under CV. Concerning Cloud Categories in DoDAF, SaaS is noted in SvcV and CV. In addition to PaaS and IaaS, Cloud Computing is also addressed under CV. With regard to Web Service/SOA elements in DoDAF, in the DoDAF generic meta-model, a service (including business and software services), a service port and performer (both service consumer and provider) are identified. The main viewpoint that has Web Service/SOA elements is SvcV. However, these elements appear in other viewpoints, such as AV and CV, when mapping services to capabilities (Alwadain, 2013).

4.4 MODAF (British Ministry of Defence Architecture Framework)

MODAF defines a normalized way of conducting Enterprise Architecture, and it was originally developed by the UK Ministry of Defence (MOD). MODAF is an internationally normalized EA framework developed by MOD to support Defence planning and change management activities (ISO/IEC JTC 1/SC7 Architecture Guidance, Garnier et al., 2014). MODAF provides a consistent set of rules and templates, known as views, that present a textual and graphical visualization of an area of the business. Each view provides a special perspective of the business in order to meet various stakeholder concerns. The views are divided into seven categories: strategic, operational, service-oriented, systems, acquisition, technical, and all views. MODAF includes a meta-model that defines the relationship between all data in all the views (UK Ministry of Defence, 2010a).

With regard to Mobile IT Category elements in MODAF, although Mobile Devices are noted in strategic and system viewpoints, the focus is from a Mobile Network perspective. Moreover, there are no Cloud Category elements in MODAF. Web Service/SOA-related elements identified in the MODAF models are service, service interface, and service consumer in the service-oriented viewpoint (UK Ministry of Defence, 2010b). In addition, there is note of Application Services under the service-oriented viewpoint.

4.5 Adaptive Enterprise Architecture Framework

The adaptive enterprise architecture framework (also known as the Gill Framework) is a meta-framework that can be used to support the tailoring of a situation-specific adaptive enterprise architecture capability or framework (Gill, 2013). This framework provides support for developing and managing adaptive or agile enterprise architecture in a modern context, including adaptive Cloud technology-enabled enterprise architecture. This framework has its foundation on the new “adaptive enterprise service system” theory, which extends the SoS, agility, and service science approaches for defining, operating, managing, supporting, and adapting a modern enterprise as an “adaptive enterprise service system” (Gill, 2013). This framework has two main layers: outer and inner. The outer layer presents five adapting capabilities (i.e., context awareness, assessment, rationalization, realization, and un-realization) to guide the continuous adaptation of the adaptive enterprise architecture as an adaptive enterprise service system in response to internal and external changes. The inner layer assists in defining, operating, managing, and supporting the complex enterprise as an adaptive enterprise service system in response to changes or requirements reported by the outer layer (Gill et al., 2014).

First, with regard to Mobile IT Category elements in an Adaptive EA framework, there is note of Mobile Devices and APIs in Cloud EA Capability. With regard to Cloud Category elements in the Adaptive EA framework, SaaS, PaaS, and IaaS reside in the Adaptive Cloud EA Model, and the Cloud Interface is described in the Adaptive Cloud EA — the model for the federated adaptive enterprise Service Information System (SIS). Furthermore, concerning Web Service/SOA elements in an Adaptive EA framework, Business, Application, Information, Infrastructure, and Platform Services reside in the Enterprise Service System meta-model and Cloud EA Model (Service Mapping — External View) and the Service-based Mobile application is described in Cloud EA Capability. Moreover, Business Interface resides in the Business Architecture Model (Internal View) of Cloud EA Capability.

5. Comparison of Mobile IT/Cloud Integration in EA Frameworks

The five selected EA frameworks are compared based on the key elements of Mobile IT/Cloud computing and Services in order to present an overview of the status in terms of the Mobile IT/Cloud elements and the position of these elements in the layers (viewpoints) of the five frameworks. Discussions and conclusions based upon this comparison are presented in the following sections.

First is the Mobile IT Category. The Mobile IT-related elements are identified in all frameworks. For instance, mobile device is found in the FEAF meta-models in IRM and SRM, and FEAF documents in BRM and ARM. Moreover, mobile device is identified in the TOGAF, DoDAF, MODAF, and Adaptive EA framework documents. An API is found in the FEAF meta-model in ARM, and FEAF documents in DRM. Furthermore, an API is presented in the TOGAF and Adaptive EA framework documents. However, *Mobile Device Manager* and *Mobile Application controller* are not found in all frameworks.

Second is the Mobile IT-related Cloud computing category. Many elements of “Mobile IT-related Cloud computing” that involve SaaS, PaaS, and IaaS are found in the meta-models of Adaptive EA framework. Moreover, SaaS is identified in the FEAF document in IRM, and DoDAF documents. PaaS and an IaaS are used in the FEAF document in IRM and DoDAF document. Furthermore, other Cloud-related elements are identified in the FEAF meta-model in IRM and FEAF documents in ARM and SRM, and in the DoDAF document. Moreover, in the Adaptive EA framework documents, a Cloud Interface is found.

Third is the Services category. The service is identified in all frameworks, but it varies remarkably in the details. For instance, a generic service element is found in the meta-models of DoDAF, MODAF, and Adaptive EA framework, whereas a business service is recognized in the meta-models of TOGAF, FEAF, and Adaptive EA framework, and in the DoDAF documents. In addition, an application service is identified in the TOGAF and Adaptive EA framework meta-models, and in the FEAF, DoDAF, and MODAF documents. Furthermore, an Information System service is found in the TOGAF and Adaptive EA framework meta-models, and an enterprise service is identified in the FEAF and Adaptive EA framework documents. Moreover, an infrastructure service is presented in the Adaptive EA framework meta-model, and in the TOGAF and FEAF documents, whereas a platform service is used in the TOGAF and Adaptive EA framework meta-models. From the perspective of Microservices and Application, Information System, and Platform services in SOA, these are equivalent to Functional services. Service-based Mobile Application is not found in all frameworks, with the exception of Adaptive EA framework. In terms of Microservices, Infrastructure service in SOA is equivalent to infrastructure service, whereas Business service in SOA is close to Microservices.

Fourth is the Actors category. In the Adaptive EA framework meta-model, an actor is identified in the business layer and in the TOGAF and FEAF documents in BRM and SRM. A service consumer is presented in the MODAF meta-model and in the TOGAF, FEAF, and Adaptive EA framework documents. Moreover, a service provider is used in the TOGAF and MODAF documents, and FEAF documents in BRM, whereas a performer that could be a service provider or consumer is presented in the DoDAF meta-model and documents.

Fifth is the Interfaces category. A Business Interface is identified in the Adaptive EA framework meta-model. Moreover, Application and Infrastructure interfaces are found in the Adaptive EA framework documents. However, in the DoDAF meta-model, it is called a service port, whereas in the TOGAF, FEAF, Adaptive EA framework documents, and MODAF meta-models, it is called a service interface.

6. Discussion

The analysis from previous sections resulted in several beneficial findings. First, the Mobile IT element is recognized in the frameworks. A mobile device and/or API were identified in most layers (viewpoints) of TOGAF, FEAF, and Cloud EA Capability of Adaptive EA framework. Moreover, only the mobile device was found in DoDAF and MODAF. However, all frameworks did not include the elements of a Mobile Device Manager and Mobile Application controller at the current time, which can lead to difficulties for making proper architecture models/guidelines for Mobile IT to promote EA.

Second, most frameworks have elements of Cloud computing related to Mobile IT, with the exception of TOGAF and MODAF. All the elements of Cloud computing related to Mobile IT, such as SaaS, PaaS, and IaaS, are included in FEAF, DoDAF, and Adaptive EA framework meta-models. Because the US government agency promotes the IT strategy called “Cloud First”, where shared services become suitable for budget reduction and optimization with common sense approaches, Cloud IRM defined in FEAF has the elements of SaaS, PaaS, and IaaS. In terms of DoDAF, SaaS is found in the description of “DoDAF Meta Model for Services”, whereas PaaS, IaaS, and SaaS are identified in the description of “service-centric IE capability”. The Cloud interface is identified only in Adaptive EA framework. Because all frameworks do not have the Cloud Interface indispensable for implementation of the Hybrid Cloud-based system in companies, with the exception of the Adaptive EA framework, it is obvious that few model-defining Hybrid Clouds appropriate for companies exist in EA frameworks. Therefore, it will be considered that the corporation adopting frameworks such as TOGAF, etc. can adopt the integrated framework with the Adaptive EA framework supporting elements of Cloud computing to meet the shift to Cloud computing environments in future. In addition, concerning the Zachman framework, Zachman has published an Official Newsletter specific to the Cloud Category that mentions a definition of Cloud computing within Physical and Detailed Views (Zachman, 2011). Moreover, Laplante et al. (2008) defined SaaS within an entire view of contextual, conceptual, logical, physical, detailed, and functioning.

Third, all frameworks have a service element, but some differences are observed by examining further and comparing systematically. A business service is included in most EA frameworks. An application service is also included in most frameworks. However, the IS, enterprise, and platform services are less frequent. Each of these is covered in one framework and the Adaptive EA framework. Although the Platform service is presented in TOGAF and Adaptive EA framework, the infrastructure service is used in these frameworks as well as FEAF — they have similar semantics. Furthermore, it is apparent that TOGAF has a clear categorization and representation of services in all their layers (viewpoints). A Service-based Mobile Application is found only in the document of the Adaptive EA framework. On the other hand, few service elements described as Microservices are found in all frameworks at the current time.

Fourth, the actor element is included in the frameworks. An actor as a generic element is discovered in TOGAF to represent both the service provider and consumer. The separation of the provider from the consumer in two elements is only observed in FEAF (Alwadain, 2013). In Adaptive EA framework, only service consumer is found in two elements. The actor element is similar to many of the other elements in terms of terminology discrepancy, regardless of whether a generic actor element is used to represent both the provider and consumer (Alwadain, 2013).

Fifth, all frameworks have an interface element, but some differences are identified by comparing them. In terms of the service interface, all frameworks contain interfaces as part of SOA. However, interface-related elements are represented through different terms in the various frameworks. For example, in DoDAF, the term “service port” was chosen instead of “service interface” (Alwadain et al., 2014). Adaptive EA framework includes business, application, infrastructure, and service interfaces.

Furthermore, it appears that the presented frameworks can generally or partially accommodate the elements that constitute the categories of Mobile IT/Cloud computing and services as part of SOA. However, there are few elements of Mobile IT and related Cloud computing, which is beneficial to the definitions of architecture models/guidelines/processes in Mobile IT and related Cloud computing to promote EA in corporations. In specific, in terms of the Mobile IT Category, the existing EA frameworks have not supported the essential mechanisms of this one to date because most elements, such as Mobile Device Management, Mobile application, and its controller, are not included in all EA frameworks at the current time. We concluded that there should be a problem where there is no element useful for defining proper architecture models/guidelines/processes in Mobile IT and related Cloud computing in all frameworks to promote EA.

7. Conclusion

In this paper, five EA frameworks were investigated and compared in terms of Mobile IT/Cloud computing and Service elements. They all supported service elements at different levels and almost all included the elements of Mobile IT/Cloud computing, even if partially. However, although only Cloud computing elements were found in the Adaptive EA framework and FEAF meta-models, which led to architecture models/guidelines/processes for Cloud computing, there were few elements of Mobile IT and related Cloud computing effective for making appropriate architecture models/guidelines/processes in Mobile IT and related Cloud computing to promote EA in corporations. For instance, there was no element of Cloud Interface in the meta-models of all frameworks, which is essential for defining a Hybrid Cloud system, whereas there was no element of Mobile Device Manager, Mobile Application controller, or Mobile Application in the meta-models of all frameworks. The problem to be solved is that there is no effective element for making appropriate architecture models/guidelines/processes in Mobile IT and related Cloud computing in all frameworks to promote EA that can lead to business contributions, cost reductions, and profit increase in corporations. For the purpose of coping with these matters with regard to Mobile IT/Cloud computing integration in EA frameworks, we propose to establish “TOGAF Guidelines for Mobile IT” and “TOGAF Guidelines for Cloud computing”, “TOGAF Guidelines for Microservices” as “TOGAF Guidelines for SOA” was published several years ago. Moreover, we are hopeful that the architecture reference models for Mobile IT/Cloud computing will be established in DoDAF in the future. On the other hand, it will be useful for the architecture meta-models of Mobile IT and Microservices to be defined in the Adaptive EA framework in the future.

The contribution of the paper is that, to the best of our knowledge, this is the first paper to compare EA frameworks with a focus on the Mobile IT/Cloud computing elements integrated into those frameworks. Moreover, this study will be the first step in understanding and improving the integration of Mobile IT/Cloud computing with Service in EA. This study will be the preparation for defining appropriate architecture models/ guidelines/processes in Mobile IT and related Cloud computing to promote EA as a very important factor of IT Governance in corporations for the future. On the other hand, for practical reasons, although the study referred to the relationships and interactions among the elements of Mobile IT/Cloud computing and Service, it could not analyze their relationships in EA frameworks because of space restrictions. Future research needs to look beyond existing literatures to better identify the role of Mobile IT/Cloud computing with services for EA to define architecture meta-models in Mobile IT and related Cloud computing. It can be proposed as a good option that a company having applied frameworks such as TOGAF or FEAF, etc. can adopt the integrated framework with the Adaptive EA framework supporting elements of Cloud computing to meet the trend shift to Cloud computing/Mobile IT environments from now onwards. Furthermore, the IoT (Internet of Things), which is an important category of Digital IT, also has architecture elements similar to Mobile IT/Cloud. The IoT consists of IoT devices such as sensor/control/RFID tags and Web service APIs, according to the definitions of models related to the IoT and also to big data analytics in Open Platform 3.0 Standard. Moreover, the IoT can involve the SaaS Cloud model as software becomes more deeply integrated in the machines around us (Loukides & Bruner, 2015). Therefore, there is a possibility that these proposed EA frameworks can also be applied in the IoT/Digital IT fields. Future research needs to verify these proposed EA frameworks, such as surveys and case studies, while being able to consider utilizing quantitative analysis/methodologies to clarify the practical values of these proposed EA frameworks in an applicable manner. Further research is required to explain the differences in the integration approaches that could be generalized to new emerging concepts, such as Mobile IT/Cloud computing inclusive of the IoT/Digital IT, that need to be integrated in the EA frameworks.

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