DEFINING A SET OF ARCHITECTURAL REQUIREMENTS FOR SERVICE-ORIENTED MOBILE LEARNING ENVIRONMENTS

Nemésio Freitas Duarte Filho and Ellen Francine Barbosa
University of São Paulo (USP) - Institute of Mathematics and Computer Science - ICMC

ABSTRACT

Even providing several benefits and facilities with regard to teaching and learning, mobile learning environments present problems and challenges that must be investigated, especially with respect to the definition and standardization of architectural aspects. Most of these environments are still built in isolation, with particular structures and architectures, hindering aspects such as reuse and interoperability, for instance. On the other hand, several initiatives of using service orientation aspects to support and help the architectural definition of software systems have been investigated. Motivated by this scenario, in this paper we propose a set of architectural requirements for service-oriented mobile learning environments. The architectural requirements are defined by means of a systematic process, being prioritized and complemented with the help of domain experts. In the very end, the main goal is to provide an adequate support for the architectural design of mobile learning environments, promoting quality, interoperability, reuse and reduction of the time spent in the development of such environments.

KEYWORDS

Architectural Requirements, Mobile Learning Environment, Service Orientation.

1. INTRODUCTION

Virtual learning environments, together with the advent of ubiquitous computing, have provided a new and innovative way of education – the mobile learning (*m-learning*) (Martin, 2010). In short, m-learning is characterized by the ability to promote a strong interaction among apprentices, teachers and tutors, enabling them not only to access the learning environment but also to contribute and actively participate of the knowledge construction process through mobile devices (e.g., mobile phones, tablets, laptops, radio, tv, among others).

Despite the benefits provided, mobile learning is still faced as a new and incipient concept, presenting some limitations that difficult its effective adoption, such as (Jong et al., 2008): (1) reduced processing power; (2) variable screen size; (3) limited energy (battery dependent); (4) transmission rates that are generally smaller than those of the fixed network; (5) adequacy to usability aspects; and (6) lack of architectural patterns.

Considering the need of building quality and reusable mobile learning environments, efforts for developing architectural patterns have become increasingly relevant. Software architectures dealing with aspects of SOA (Service-Oriented Architecture) have gained particular importance within the context of mobile learning (Otón et al., 2010; Palanivel and Kuppuswami, 2011). However, in spite of such efforts, there is still a lack of a standardized set of architectural requirements, specifically defined to the mobile learning domain and in accordance with service-oriented issues.

In short, an architectural requirement can be defined as any requirement that is architecturally significant (e.g., performance, usability, reuse, security, interoperability, adaptation, among others), with particular responsibilities in relation to a given software domain (Schepman et al., 2012). The right definition of these requirements provides a better abstraction of the system to be developed, helping and supporting its architectural representation.

Motivated by this scenario, in this paper we propose a set of architectural requirements for service-oriented mobile learning environments. The requirements are defined through a systematic process, which supports the design, prioritization and complementation of architectural requirements. In the end, we intend to promote interoperability, domain comprehension, architectural reuse, better quality and reduced time spent in the development of these environments.

2. BACKGROUND

M-learning has appeared as a new type of electronic learning, taking place when the interaction among the actors of the learning process is performed through mobile devices. As a new and emerging paradigm, there are several attempts for defining m-learning. According to Schepman et al. (2012), m-learning refers to any kind of learning that occurs when the apprentice is not in a fixed place, or when he/she takes advantage of learning opportunities provided by mobile devices, thereby relating technological and mobility concepts. Ozdamli and Cavus (2011), in turn, address m-learning as an activity that allows individuals to be more productive when they consume, create or interact with information, supported by mobile devices.

No matter the definition adopted, the use of learning environments through mobile devices provides benefits that go beyond accessibility, convenience and communication (Schepman et al., 2012). However, despite the advantages offered and even with the increasing research related to the development of mobile learning environments, there are few works dealing with a well-established set of architectural requirements in this new learning setting (Efstratiou et al., 2000).

Due to the complexity and lack of architectural standardization regarding m-learning environments, difficulties concerning the use, integration, maintenance and reuse of these environments are still common during their development. In this sense, the adoption of a SOA approach can make the construction and adoption of m-learning environments be easier and more flexible, promoting interoperability and reuse of best practices in the educational scenario (Erl, 2009).

Some initiatives regarding the definition of service-oriented architectural requirements for m-learning environments can be found in the literature (Section 3.1). Such initiatives, however, are spread out, with no kind of standardization with respect to educational practices and issues of mobility and service-orientation (Erl, 2009; Otón et al., 2010; Basaeed et al., 2007; Thanh and Jorstad, 2005). Besides that, the establishment of architectural requirements for software systems in general, and for mobile learning environments in particular, is not a trivial task (Efstratiou et al., 2000). Guidelines to support the architectural design process and, at the same time, ensure the correct understanding of the specificities of the target domain, are required (Duarte Filho and Barbosa, 2013).

In a different but related perspective, Nakagawa and Maldonado (2007) worked on a process to support the development of reference architectures, referred to as ProSA-RA (Process based on Software Architecture - Reference Architecture). ProSA-RA focuses on how to deal with architectural aspects as well as on how to represent and evaluate reference architectures. The process comprises four basic steps: (1) Information Sources Investigation; (2) Architectural Requirements Establishment; (3) Reference Architecture Design; and (4) Reference Architecture Evaluation. In our work, we are particularly interested in Step 2 of ProSA-RA, since it establishes some general guidelines to identify and describe the common functionalities and architecture requirements presented in software systems.

Based on ProSA-RA (Step 2), we established a smaller but systematic process for the determination of architectural requirements. The process was applied in the context of mobile learning environments in order to define the architectural requirements for this domain. The process and its application are described next.

3. A PROCESS FOR THE DEFINITION OF ARCHITECTURAL REQUIREMENTS

The establishment of the set of architectural requirements for mobile learning environments was performed through the systematic process. The process comprises four main steps: (1) Application Context Definition; (2) Identification and Analysis of Information Sources; (3) Design of Architectural Requirements; and (4) Prioritization and Complementation of the Architectural Requirements.

3.1 Step 1: Application Context Definition

Due to variety of the applications for mobile learning environments (e.g., distance, simulations, games, and many others), in the first step, firstly it is necessary to set the context for which these environments will be directed, thus being able to define the most appropriate architectural requirements for the environment. The application context was defined for mobile learning environments that can support traditional courses at undergraduate level and that can support learners in relation to basic education activities (e.g., activities submission, messaging, access to educational materials, among others). Teachers and tutors, which will also benefit of the environment, can monitor and track the activities of the apprentices. This context was defined due to the authors' experience in this application domain, experiencing and using daily environments in this learning setting. This facilitates the identification of advantages and disadvantages in an educational environment.

3.2 Step 2: Identification and Analysis of the Information Sources

In this step, the idea is to get considerable knowledge about the target domain. This knowledge acts as a basis for the establishment of the architectural requirements. In our case, three groups of information sources were defined, based on their relevance in the context of mobile learning environments and SOA: (1) Concrete Architectures for Mobile Learning Environments; (2) Reference Models/Architectures for the Educational Domain; and (3) Service-Oriented Architectures.

3.2.1 Concrete Architectures for Mobile Learning Environments

In general, the research works analyzed in this group address issues related to communication, security, modularity, adaptation to the context and interoperability through service-orientation.

Otón et al. (2010) highlight two relevant aspects regarding the development and implementation of a learning system – reuse and interoperability among repositories of learning objects. Similarly, these aspects remain significant for investigation in mobile learning environments as well. In this sense, the authors presented a service-oriented architecture, implemented through web services, as a means to provide the recovery of learning objects.

In the same perspective, Palanivel and Kuppuswami (2011) define a reference architecture for service-oriented learning environments. The service-oriented aspects provided higher interoperability, reuse, modularity and scalability to the educational practices.

Jong et al. (2008) discuss a reference model for social mobile systems such as social networking and learning systems. These systems are used by multiple users, allowing intercommunication among other participants. The reference model particularly focuses on issues of communication, adaptation to the user's context and security when exchanging information (to ensure confidentiality and integrity).

The MOBIlearn project (Lonsdale et al., 2004) defines several educational services focusing on the user's adaptation. Thus, adaptation is a relevant issue to virtual learning environments, since the student's behavior is modified according to: (i) the inherent characteristics of the environment; and (ii) the content with which the student interacts.

Basaeed et al. (2007) propose an architecture for contributing to the learning process by means of web standards and web services. The authors apply a systematic approach to identify components based on the contextualization of learning, establishing their functionalities and features through web services.

Thanh and Jorstad (2005) propose a service-oriented architecture for mobile services. The requirements considered in the architecture are identified from a generic model of mobile services, which specifies: services for content delivery, services of user's management, scalability, addition of new services and security, among others.

Trifonova and Ronchetti (2004) also propose a generic architecture for supporting mobile learning. In such architecture, the functionalities of learning environments are presented as web services aiming at providing scalability, interoperability and reusability of educational content. Furthermore, characteristics such as communication and adaptation should also be addressed in the context of mobile learning environments. Actually, these characteristics, together with the characteristics of web services (discussed in Trifonova and Ronchetti, 2004 and Basaeed et al., 2011), are important in order to promote portability, reuse and scalability.

Differently from the works presented so far, Martin (2010) analyzes the need for a secure and interoperable architecture. The architecture proposed in his work establishes some basic features with respect to a generic learning environment, such as: privacy, scalability, synchronization, extensibility and reusability, distributed resources and learning resources.

From the study and analysis of the works summarized in this section, a preliminary set of architectural aspects with respect to architectures for mobile learning environments has been identified, highlighting the need for studying and adopting service-oriented aspects, such as: (1) service orientation: to allow more flexibility and interoperability; (2) adaptation to context: to provide the users a context-based learning according their location and the type of application; (3) communication: to guarantee a standardization among the data communication models; (4) security: to provide a private and reliable environment and, at the same time, synchronized with other system users; and (5) modularization: to be structured in modules and components in order to promote a better reuse, modification and quality through the lifecycle.

3.2.2 Reference Models/Architectures for the Educational Domain

The analysis of reference architectures is particularly relevant to the identification of architectural requirements, since from their representations and descriptions is possible to identify general concepts related to educational practices.

The MoLE Project (2013) specifies a reference architecture structured in components and layers to specifically suit the main practices and activities of m-learning. The proposed architecture is based on a set of mobile educational services (e.g., user authentication, data synchronization and reporting) whose goal is to enable a better integration among educational environments.

Additionally to the basic services related to integration of the mobile services, the architecture has a module, the "mobile authoring tool", that allows the creation and sharing of educational content in a mobile way. Some of the main functionalities provided by this module are: (1) creation of tasks; (2) creation of automatic evaluations; (3) creation of quizzes and questionnaires; (4) creation of didactic materials; (5) creation of exercises and tests; and (6) creation of online evaluations.

In another project, the IMS Global Learning Consortium (2013) proposes an educational reference architecture focused on service orientation. The initiative establishes guidelines with respect to the integration and representation of educational practices, without addressing however mobility and ubiquitous issues. The architecture is structured in four layers: (1) application layer; (2) application services layer; (3) common services layer; and (4) infrastructure layer. A set of educational services for supporting educational practices is also proposed: (i) course administration services; (ii) authoring services; (iii) evaluation and communication; (iv) delivery of educational content; (v) customization; and (vi) course documentation.

Finally, based on a detailed analysis of features and functionalities of several different learning environments, Barbosa et al. (2013) propose a reference architecture for learning environments, referred to as EducAR. Particularly, EducAR has an authoring module, responsible for supporting the development of educational content. Basically, this module addresses issues such as: (1) content structuring and modeling; (2) content edition; (3) automatic generation of content; (4) sharing, reuse and integration of content; and (5) content capture. Since EducAR has been developed for "traditional" learning environments, mobile issues have not been addressed on its definition.

Based on the results discussed in this section, key concepts representing the basic functionalities of mobile learning environments could be determined. Thus, the set of architectural requirements should take in consideration concepts (and their relation with educational practices) such as: (1) adaptation to context; (2) adaptation to learning standards; (3) user management; (4) course administration; (5) content authoring; (6) content delivery; (7) user evaluation; (8) course and system documentation; (9) communication; and (10) customization.

3.2.3 Service-Oriented Architectures

In order to identify characteristics for providing a better reuse and interoperability of services among mobile learning environments, aspects of service orientation should also be considered. Specially, we have investigated models and reference architectures for service orientation, as discussed next.

Alzaabi et al. (2010) propose a reference architecture for the architectural description of SOA. As a complement, Zimmermann et al. (2009) define a reference architecture to ease and support the development of service-based systems.

The OASIS project (2006) establishes a common vocabulary and a reference model for the service-oriented architectural style. The model defines relationships and main concepts regarding the SOA domain, such as: visibility, description of services, policies and contracts, ways of interaction, and execution context.

Finally, based on different implementations of service-oriented systems, Dillon et al. (2007) deal with a reference architecture based on reverse engineering. This architecture takes into consideration the analysis and addition of requirements (functional and nonfunctional) already implemented, being supported by the best practices of implementation of service-oriented systems.

From the works analyzed, we point out as the main concepts and functionalities required for the development of a service-oriented system: (1) service description; (2) service publication; (3) service interaction; (4) governance; (5) quality of service; (6) service composition; and (7) policies.

3.3 Step 3: Design of the Architectural Requirements

In this step, all the characteristics previously identified (Step 1) must be analyzed and mapped into architectural requirements. In our case, the mapping was performed with the help of researchers and domain experts in order to facilitate the determination of the relevant architectural requirements to the context of mobile learning. Additionally, the architectural requirements defined were also analyzed with respect to a set of mobile learning environments, aiming at verifying the relevance of these requirements in real learning environments. The environments considered for this analysis/comparison were: *Blackboard Mobile*[1]; *Desire2Learn*[2]; *Mobl21*[3]; *Amadeus Mobile*[4]; *MLE Moodle*[5]; e *Mobile Sakai*[6]. Such environments were chosen based on their good rates of usage by learners, teachers and tutors.

3.4 Step 4: Prioritization and Complementation of the Requirements

In order to validate the requirements identified in Step 3, the next step of the systematic process consists of conducting a prioritization and complementation of such requirements with the support and knowledge of specialists. Priorities were defined throughout of research with the help of 50 domain experts, which participated in online interviews conducted through checklists. Of the 50 specialists, 33 answered the checklist, providing feedback regarding the requirements defined. The checklist was created as a template in order to facilitate its application by the evaluator.

The prioritization was denoted by the symbols: *(NA)* Not Applicable; *(+)* Unsatisfying; *(++)* Regular; and *(+++) S*atisfactory. The idea is to denote the relevance and impact that these requirements have on service-oriented mobile learning environments. It is worth to notice that the architectural requirements prioritized as (NA) were discarded from the set of architectural requirements, since their applicability was not verified in the prioritization.

4. ARCHITECTURAL REQUIREMENTS FOR M-LEARNING ENVIRONMENTS

After the prioritization and complementation, the requirements were mapped into a set of architectural requirements for service-oriented mobile learning environments. In short, the set of requirements was defined by four specific areas, being divided into four distinct groups: Architectural Requirements for Learning Environments in General (AR-GSL); Architectural Requirements for Mobile Learning Environments (AR-ML); and Architectural Requirements specific to SOA (AR-S).

---

[1] http://www.blackboard.com/platforms/mobile/overview.aspx
[2] http://www.desire2learn.com/
[3] https://www.mobl21.com/
[4] http://amadeus.cin.ufpe.br/index.html/
[5] http://mle.sourceforge.net/
[6] https://confluence.sakaiproject.org/display/MOBILE/Home

4.1 Architectural Requirements for Learning Environments in General

1-AR-GSL (+++) - The architecture should support/enable the development of learning environments that **provide information about the course**;

2-AR-GSL (+++) - The architecture should support/enable the development of learning environments that **provide information about the system/environment;**

3-AR-GSL (+++) - The architecture should support/enable the development of learning environments that **allow the customization** of the educational content;

4-AR-GSL (+++) - The architecture should support/enable the development of learning environments that **automate the evaluation process**;

5-AR-GSL (+++) - The architecture should support/enable the development of learning environments that **support the authoring of didactic material**;

6-AR-GSL (+++) - The architecture should support/enable the development of learning environments that **provide security** to their users in relation to aspects of mobility;

7-AR-GSL (+++) - The architecture should support/enable the development of learning environments that **enable the management of content** by the instructors and administrators;

8-AR-GSL (+++) - The architecture should support/enable the development of learning environments that **enable learners' evaluations**, in a formal or informal way;

9-AR-GSL (+++) - The architecture should support/enable the development of learning environments that **support the delivery of didactic material**, being possible to explore different media interactions;

10-AR-GSL (+++) - The architecture should support/enable the development of learning environments that **provide feedback mechanisms for evaluation**, which can be conducted by means of scores, reports or even messages;

11-AR-GSL (+++) - The architecture should support/enable the development of learning environments that **manage the users and courses**, with different profiles and visions.

4.2 Architectural Requirements Specific for Mobile Learning Environments

1-AR-ML (+++) - The architecture should allow the development of m-learning environments that **manage the use of resources**, allowing the environment to use appropriate types of resources in relation to mobile devices, especially the bandwidth and memory consumption;

2-AR-ML (++) - The architecture should enable the development of m-learning environments that provides **mechanisms for the efficient energy consumption**. The idea is to ensure energy conservation techniques for mobile devices, saving power when no activity is being performed, guaranteeing greater energy autonomy over learning;

3-AR-ML (++) - The architecture should support/enable the development of m-learning environments that **allow synchronous and asynchronous communication** (among learners/tutors/system);

4-AR-ML (++) - The architecture should enable the development of m-learning environments that provide the **knowledge just-in-time**, allowing the knowledge of the learning object can be led and represented in anywhere, ensuring authenticity in their activities regardless of their location;

5-AR-ML (++) - The architecture should support/ensure **accessibility adapted for mobile devices**, supporting different languages of the communication and cognition (e.g., screen magnification/zoom, screen rotation, customization of colors and brightness);

6-AR-ML (+++) - The architecture should allow that the **upgrade and configuration** of a mobile learning environment can be performed a simple and automatic way, avoiding errors by users;

7-AR-ML (++) - The architecture should allow the m-learning environment can **synchronize and coordinate** its information with other mobile devices, allowing to the users the independence on these devices;

8-AR-ML (+++) - The architecture should support/enable the development of m-learning environments that provides **portability in relation to mobile devices** without the need to apply other actions (settings);

9-AR-ML (+++) - The architecture should support/enable the development of m-learning environments that provides features to **improve the social interaction** among users;

10-AR-ML (+++) - The architecture should support/enable the development of m-learning environments that provides **adaptation to the context**, ensuring adaptation to the user´s context in relation to physical, social and timing issues, among others.

11-AR-ML (+++) - The architecture should support/enable the development of m-learning environments that **allow collaboration among users** through wikis, forums, microblogging, social networks, among other tools.

4.3 Architectural Requirements Specific to SOA

1-AR-S (+++) - The architecture must **provide mechanisms for capturing, monitoring, registering and notifying** the non-compliance of quality requirements established among service providers and service customers;

2-AR-S (+++) - The architecture should enable the development of **scalable** educational environments, **capable of evolving incrementally** through the addition of new services;

3-AR-S (+++) - The architecture should allow the educational services that can be **treated uniformly**, i.e., can be published, located and used in the same way;

4-AR-S (+++) - The architecture should support the development of learning environments that **provide information about their characteristics and normative directions of use** through standardized descriptions;

5-AR-S (+++) - The architecture should allow that educational tools implemented in different programming languages and under different platforms **can be easily integrated**;

6-AR-S (+++) - The architecture must provide mechanisms for that didactic materials, as services, **can be published and discovered** by client applications;

7-AR-S (+++) - The architecture should allow that the educational services **can interact directly or through the use of an enterprise service bus**;

8-AR-S (+++) - The architecture should support the development of learning environments that **provide semantic descriptions**, allowing their classification in the service repositories;

9-AR-S (+++) - The architecture should support the development of learning environments that **provide information and documents related to their quality characteristics**;

10-AR-S (+++) - The architecture should enable that the mobile learning environments **communicate with other educational tools**;

11-AR-S (+++) - The architecture should allow **a partial instantiation**, that is, learning environments developed according to this architecture can be built without the need of implementing all the modules specified.

5. CONCLUSION AND FURTHER WORK

In this paper we presented a set of architectural requirements for service-oriented mobile learning environments. The requirements were elicited through a systematic process, taking into consideration: (1) application context definition; (2) the investigation of related work; (3) the analysis of existing mobile learning environments; and (4) the help/support of specialists to prioritize and complement the requirements. In the end, the proposed requirements were categorized in four groups of specific areas: (1) architectural requirements for learning environments in general; (2) architectural requirements specific for mobile learning environments; and (3) architectural requirements specific to SOA.

The main contribution of this work lies on providing guidance for architectural design of new m-learning environments as well as for evolution and maintenance of the existing ones. Indeed, the right definition of architectural requirements can promote a better abstraction of the system to be developed/evolved, helping its architectural representation. As a consequence, the determination of these requirements can provide benefits with regard to overall quality, interoperability, reuse, domain comprehension, and reduction of the time spent in the development/maintenance of m-learning environments. As further work, we intend to define a reference architecture for mobile learning environments. The architectural requirements defined in this paper will play a fundamental role in this direction, acting as the basis for the establishment of such architecture. We are currently working on this perspective; details should be reported in short term.

ACKNOWLEDGEMENT

REFERENCES

Martin, S. M., 2010. M2Learn: Towards a homogeneous vision of advanced mobile learning development. Education Engineering (EDUCOM), IEEE, p 569 – 574.

Jong, T. et al, 2008. A Reference Model for Mobile Social Software for Learning. In: International Journal of Continuing Engineering Education and Lifelong Learning, vol.18, pag.118-138.

Otón, S. et al, 2010. Service Oriented Architecture for the Implementation of Distributed Repositories of Learning Objects. In: (ICIC) International Journal of Innovative Computing, Information and Control. Volume 6, Number 3(A), March.

Palanivel, K. and Kuppuswami, S., 2011. Service-Oriented Reference Architecture for Personalized E-learning Systems (SORAPES). In: International Journal of Computer Applications (0975 – 8887) Volume 24– No.5, June.

Schepman, A. et al, 2012. An observational study of undergraduate students' adoption of (mobile) note-taking software. Computers in Human Behavior, 28(2), 308-317.

Ozdamli, F. and Cavus, N., 2011. Basic elements and characteristics of mobile learning. World Conference on Educational Technology Researches, Volume 28, p 937–94.

Erl, T., 2009. SOA: principles of service design. Pearson Prentice Hall.

Basaeed, E. I. et al, 2007. Web- Based Context-Aware m-Learning Architecture, International Journal of Interactive Mobile Technologies (iJIM), Vol. 1, No. 1, pp 1-6, Oct.

Thanh, D. V. and Jorstad, I., 2005. A Service-Oriented Architecture Framework for Mobile Services. in Advanced Industrial Conference on Telecommunications/Service Assurance with Partial and Intermittent Resources Conference/ELearning on Telecommunications Workshop, Lisbon, Portugal.

Efstratiou C. et al, 2000. Architectural Requirements for the Effective Support of Adaptive Mobile Applications. Proceedings of IFIP/ACM International Conference on Distributed Systems Platforms and Open Distributed Processing (Middleware-2000, New York, USA.

Duarte Filho, N. F. and Barbosa, E. F., 2013. A Requirements Catalog for Mobile Learning Environments. In: 28th ACM Symposium on Applied Computing (SAC 2013), Coimbra - Portugal.

Nakgawa, E. Y. and Maldonado, J. C., 2007. Representing aspect-based architecture of software engineering environments. In: Proceedings of the 1th Workshop on Aspects in Architecture Description (AOSD), Vancouver, p. 1-4, Canada.

Lonsdale, P. et al, 2004. A Context Awareness Architecture for Facilitating Mobile Learning. In: Learning with Mobile Devices: Research and Development. London. Learning and Skills Development Agency, pp. 79-85.

Trifonova, A. and Ronchetti, M.,2004. A general architecture to support mobility in learning. In 4th IEEE international conference on advanced learning technologies (ICALT'04) (pp. 26–30).

MoLe Project Mobile Learning Environment, 2013. (MoLE) Science & Technology (S&T) Technology & Transition (N11-06). Available in: https://wss.apan.org/1539/JKO/mole/. Accessed July/2013.

IMS Global Learning Consortium., 2013. The IMS Abstract Framework: White Paper. IMS Technical Report. July. Available in: http://www.imsglobal.org/af/index.cfm. Accessed July /2013.

Barbosa, E. F. et al, 2013. Establishment of a Reference Architecture for Developing Learning Environments. In: 25th International Conference on Software Engineering and Knowledge Engineering (SEKE 2013), Boston, USA.

Alzaabi, M. et al, 2010. Web-based Architecture for Mobile Learning. International Journal for Infonomics (IJI), Volume 3, Issue 1, March.

Zimmermann, O. et al, 2009. Architecture knowledge in an SOA infrastructure reference architecture. In: Software Architecture Knowledge Management, Berlin, Heidenberg: Springer-Verlag, p. 217-241.

OASIS., 2006. Reference model for service oriented architecture 1.0. Technical Report, Advanced Open Standards for the Information Society (OASIS).

Dillon, T. S. et al, 2007. Reference architectural styles for service-oriented computing. In: Proceedings of the 4th International Conference of Network and Parallel Computing (NPC 2007), Dalian, China: Springer-Verlag, 2007, p.543-555(LNCS v. 4672).